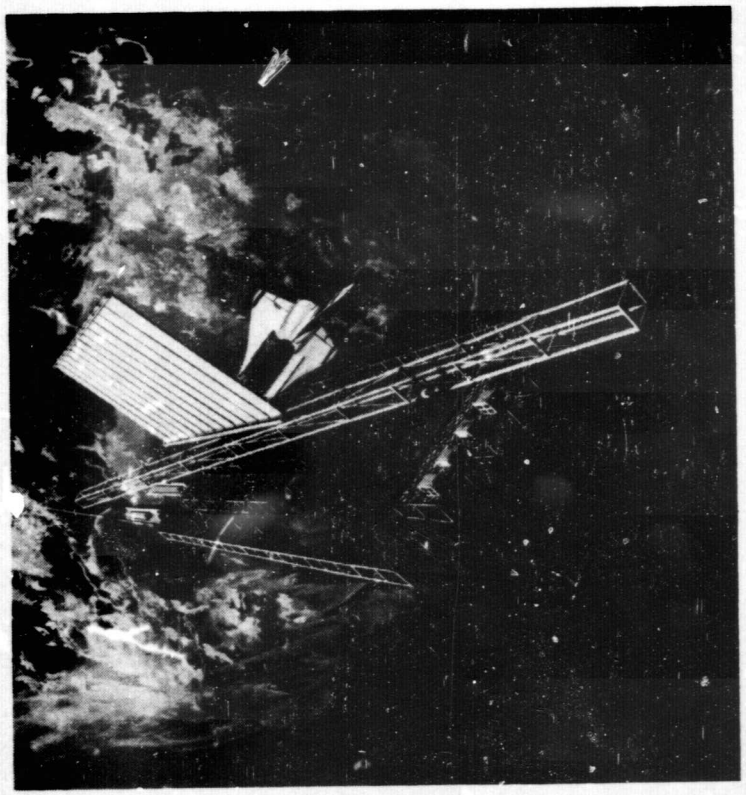
CR-151359

ORBITAL CONSTRUCTION DEMONSTRATION STUDY

FINAL REPORT

(CONTRACT NAS 9-14916)



EXECUTIVE SUMMARY

DEC 1976

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(NASA-CR-151359) ORBITAL CONSTRUCTION DEMONSTRATION STUDY. EXECUTIVE SUMMARY Final Report (Grumman Aerospace Corp.) 44 p HC A03/MF A01 CSCL 22A

N77-23138

Unclas
G3/12 26150

ORBITAL CONSTRUCTION DEMONSTRATION STUDY

FINAL REPORT

EXECUTIVE SUMMARY

(CONTRACT NAS 9-14916)

PREPARED FOR

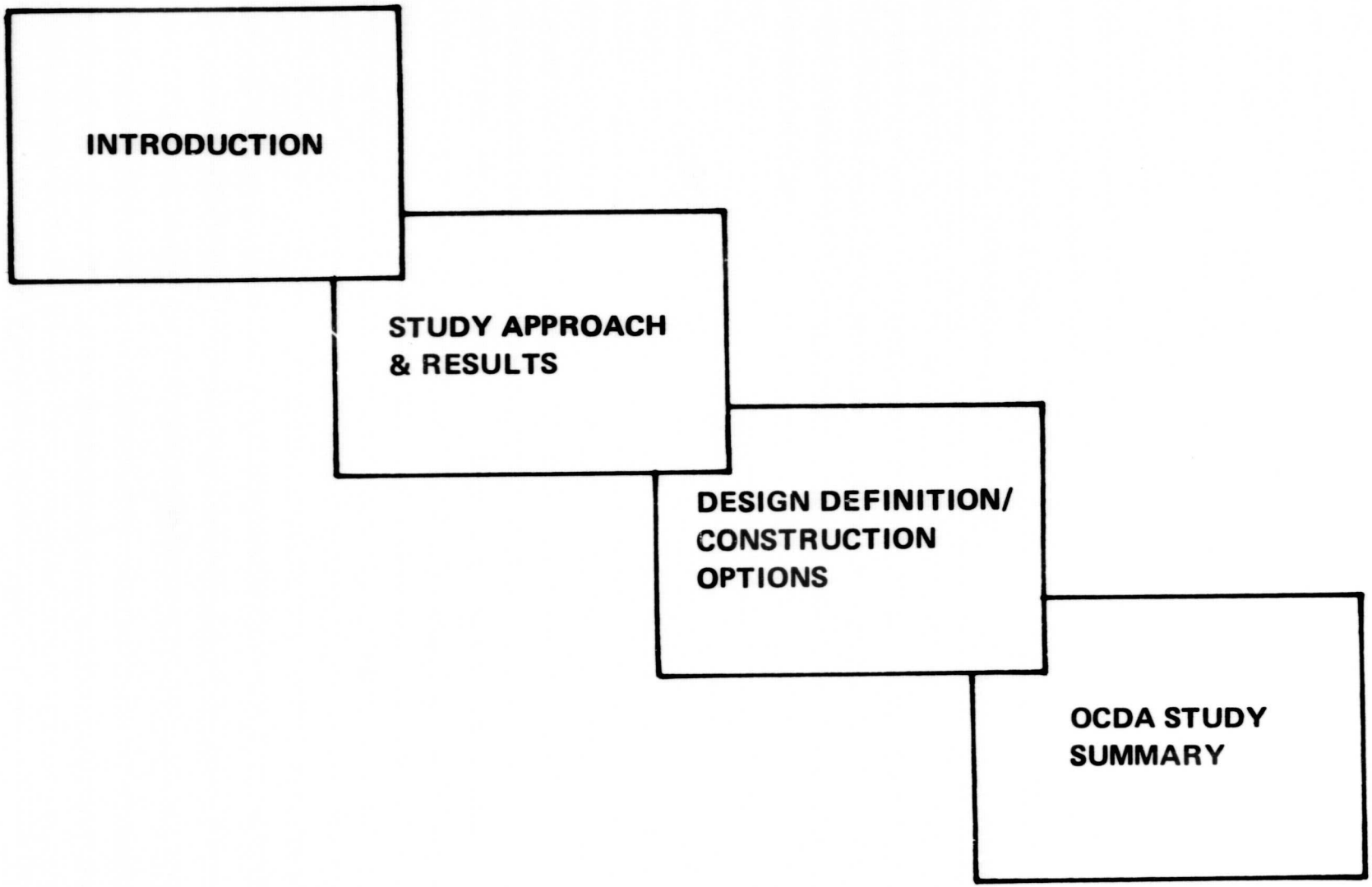
LYNDON B. JOHNSON SPACE CENTER
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
HOUSTON, TEXAS 77058

BY

GRUMMAN AEROSPACE CORPORATION
BETHPAGE, N.Y. 11714

DEC 1976

AGENDA


INTRODUCTION
STUDY APPROACH & RESULTS
DESIGN DEFINITION/ CONSTRUCTION OPTIONS
OCDA STUDY SUMMARY
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NASA/NATIONAL OBJECTIVE

- ACQUIRE ABILITY TO BUILD LARGE STRUCTURES IN SPACE
  - SOLAR POWER
  - LARGE ANTENNAS
  - ILLUMINATORS
  - ETC.
- CONSTRUCTION TECHNOLOGY ISSUES EXIST & MUST BE RESOLVED AS A PREREQUISITE TO THE ABOVE REPRESENTATIVE MISSIONS
- SOME ISSUES CAN BE RESOLVED BY GROUND TEST (E.G. MATLS & ELEMENT TESTING) BUT OTHERS (E.G. ERECTION OF VERY LARGE, LIGHTWEIGHT STRUCTURES) REQUIRE ORBITAL TESTS

THREE BASIC APPROACHES TO ORBITAL TESTING

- SHUTTLE SORTIE
- SPACE STATION
- OCDA

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ROLE OF OCDA STUDY

IN-DEPTH EXPLORATION OF SHUTTLE-SUPPORTED CONSTRUCTION BASE CONCEPT (NO PERMANENT HABITATION QUARTERS)

STUDY CONCENTRATED ON:

- REPRESENTATIVE LARGE STRUCTURES THAT CAN ONLY BE TESTED IN SPACE
- DEFINITION OF INITIAL CONSTRUCTION BASE (ADD-ON TO COVER APPLICATIONS OF FACILITY)
- PROGRAMMATIC ISSUES OF SCHEDULE & COST, & MISSION PLANS

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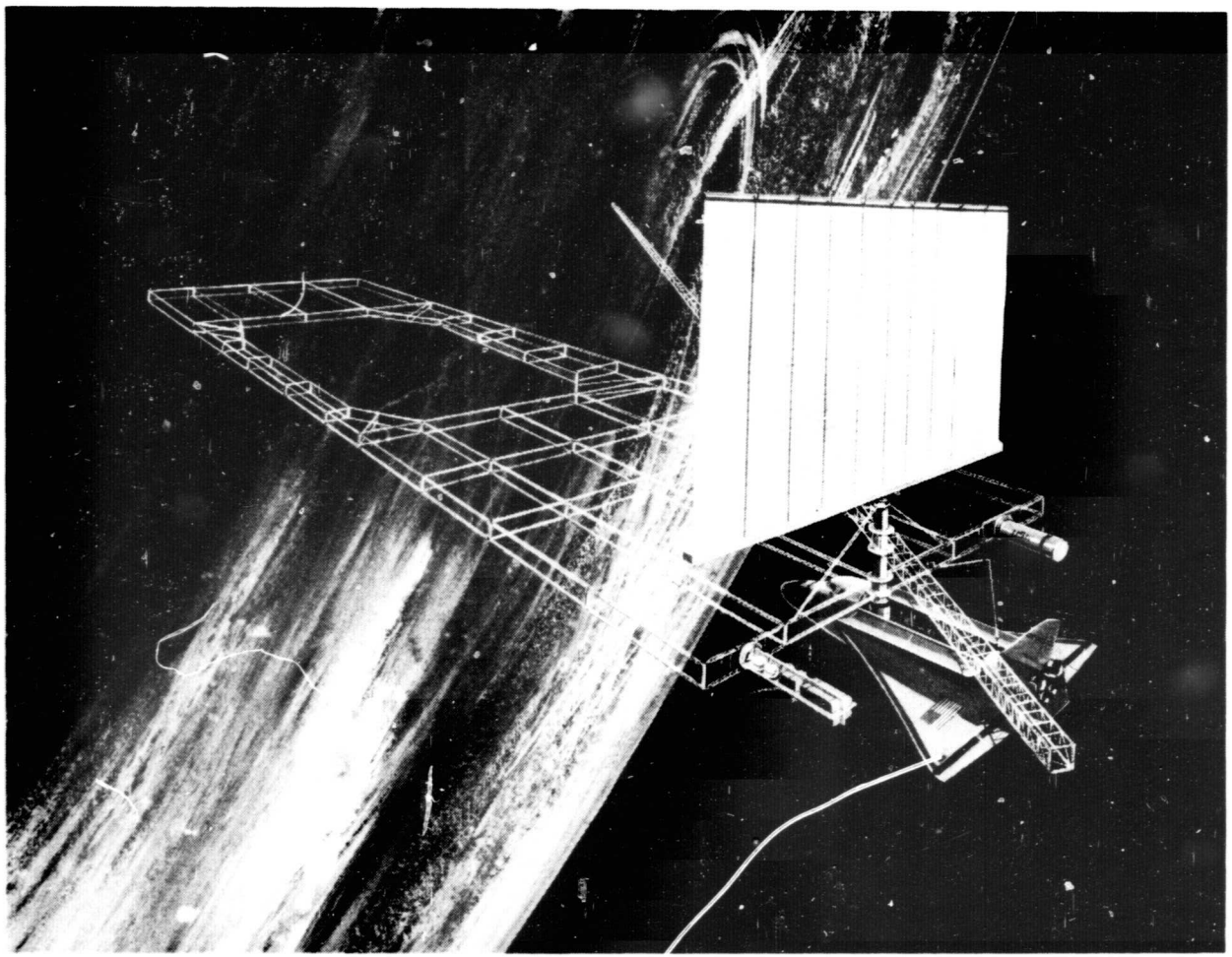

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KEY STUDY CONCLUSION

OCDA DEFINITION – KEY CHARACTERISTICS

- 250 KW POWER SOURCE
- 72 M X 32 M WORK PLATFORM
- 110 M LOGISTIC BOOM
- 37,000 KG MASS
- THREE SHUTTLE FLIGHTS
- IOC 1984
- $450 MILLION

REQUIRES EARLY PROGRAM INITIATION TO ACHIEVE IOC DATE

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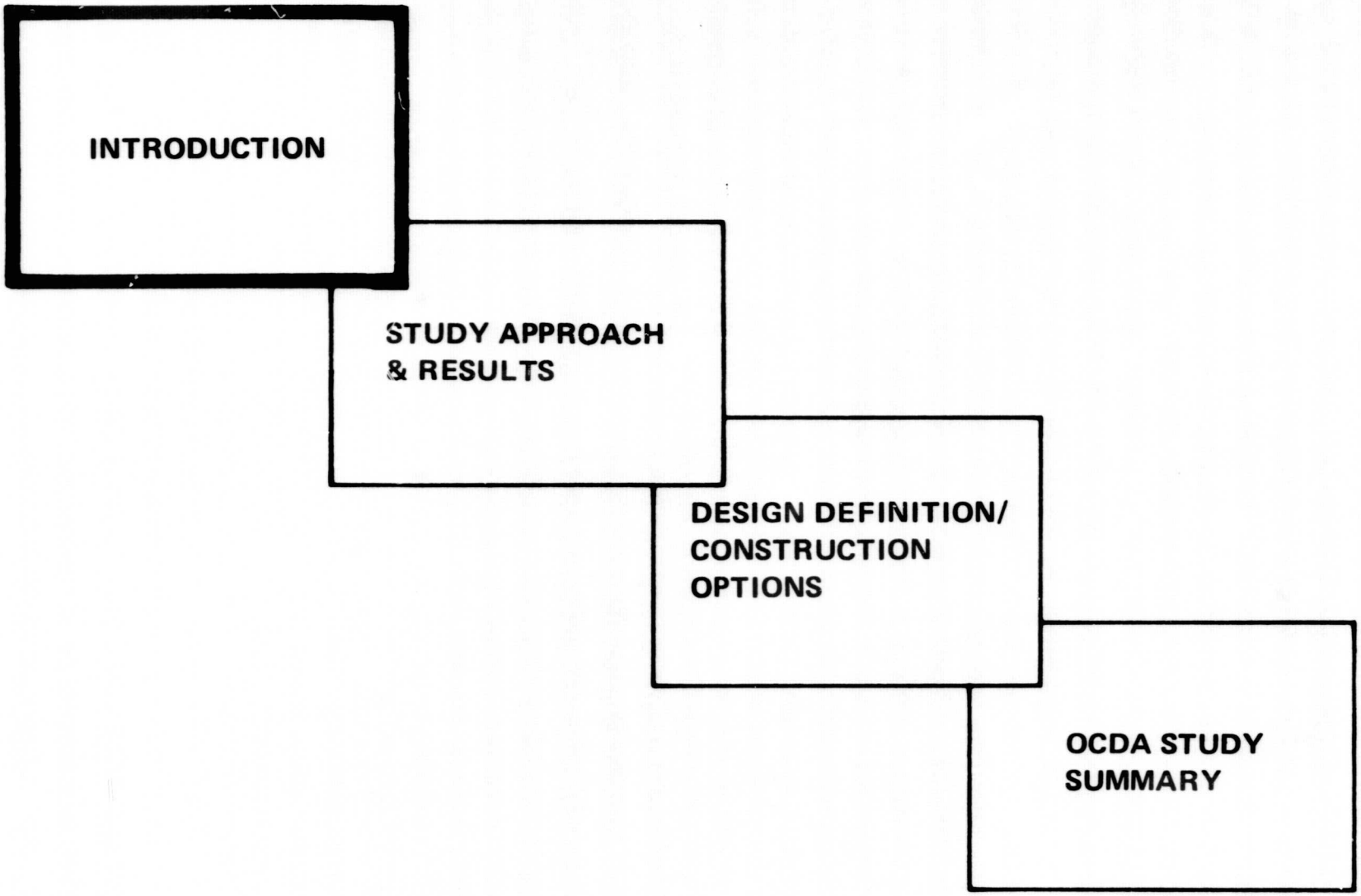
AGENDA



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STUDY OBJECTIVE/TASK DESCRIPTION

STUDY OBJECTIVE

- **DEFINE AN ORBITAL DEMONSTRATION PROGRAM THAT:**
  - **UTILIZES STS ELEMENTS**
  - **DEMONSTRATES & EVALUATES ASSEMBLY TECHNIQUES FOR USE IN CONSTRUCTING LARGE OPERATIONAL SPACE STRUCTURES**

TASKS

1. **IDENTIFY CONSTRUCTION TECH REQMTS FOR REPRESENTATIVE SPACE STRUCTURES**
2. **PROVIDE CONCEPT DESIGNS FOR DEMONSTRATION SPACE SYSTEM**
3. **PROVIDE MISSION PLANS FOR DEMONSTRATION PROGRAM**
4. **PROVIDE PROGRAM COSTS & SCHEDULES**
5. **PERFORM SUPPORTING ANALYSIS:**
   - **MISSION FEASIBILITY ASSESSMENT**
   - **CONTINUING BENEFITS ANALYSIS**

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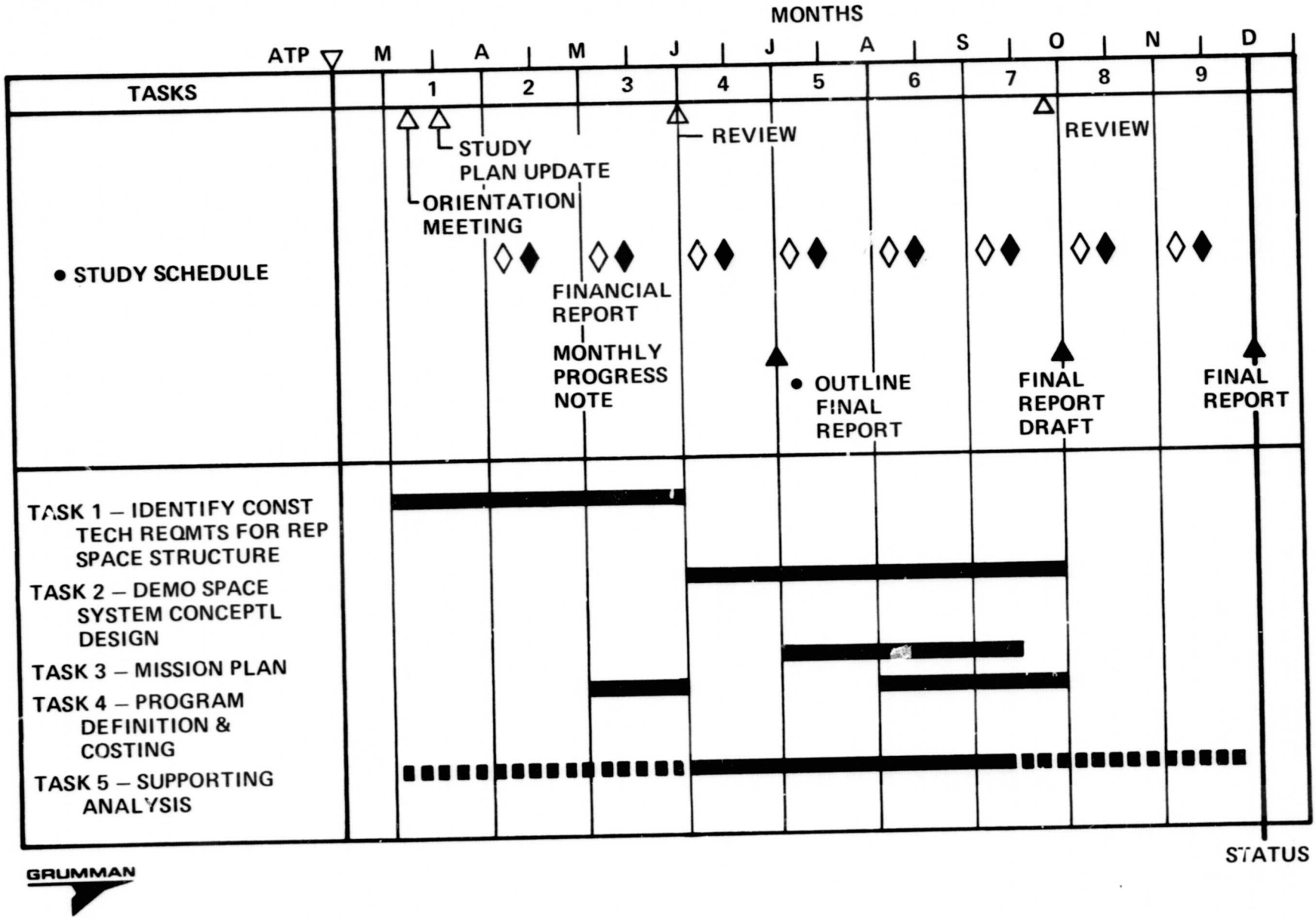
ORBITAL CONSTRUCTION DEMONSTRATION STUDY SCHEDULE



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GROUNDRULES

- SHUTTLE COMPATIBLE
  - PACKAGE VOLUME & WEIGHT
  - SHUTTLE SUPPORT EQUIPMENTS & P/L ACCOMMODATIONS
  - CREW EVA ACTIVITY CONSTRAINTS
- 2 TO 6 FLIGHTS FOR INITIAL PLACEMENT
- 1981 TECHNOLOGY BASE
- IOC 1984
- CONCENTRATE ON INITIAL DEPLOYMENT (IDENTIFY CONCEPTS FOR CONTINUED UTILITY)

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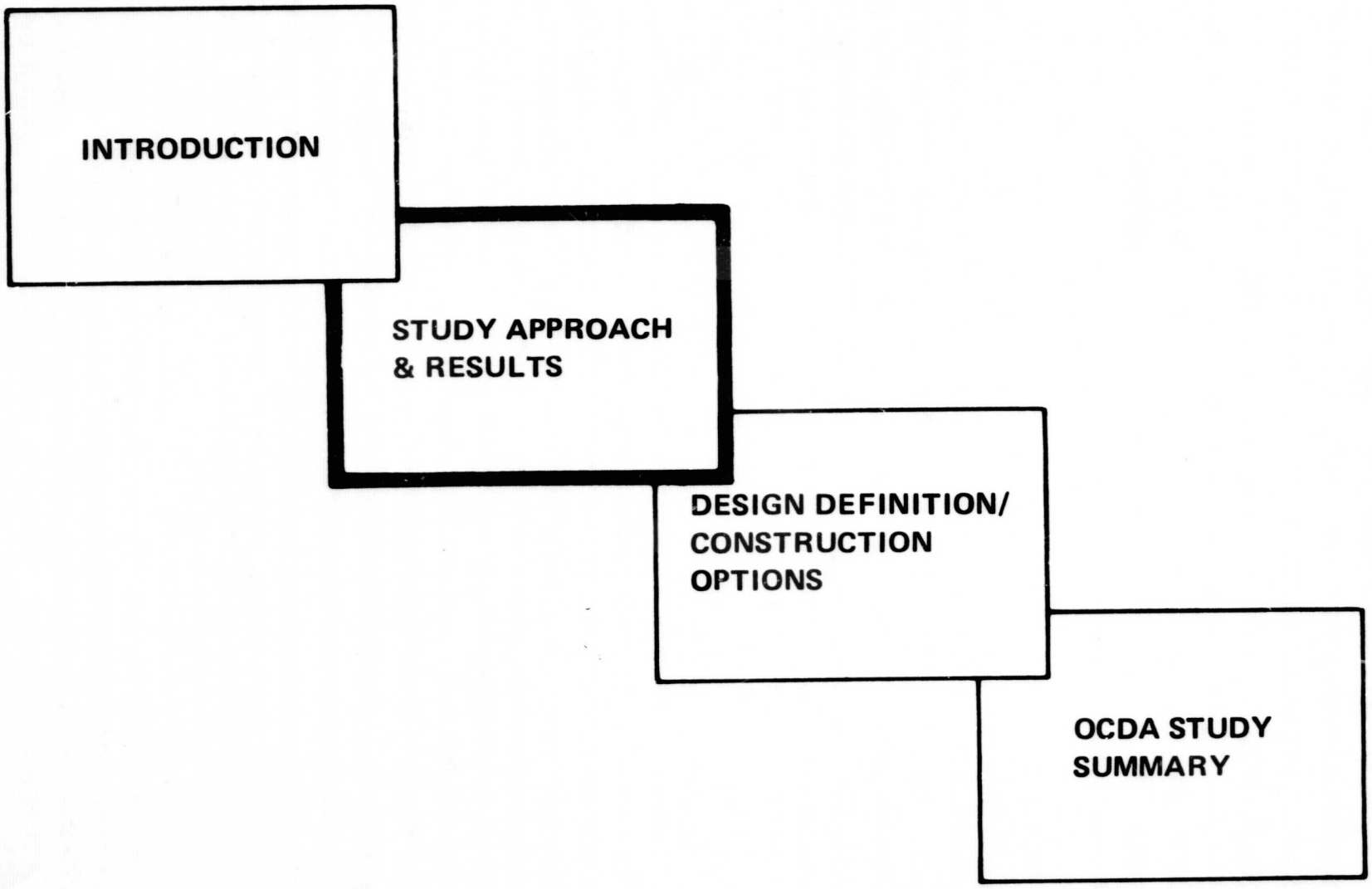
AGENDA



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STUDY APPROACH

- IDENTIFY POTENTIAL LARGE STRUCTURE BY REVIEW OF FUTURE MISSIONS
- SELECT REPRESENTATIVE MISSIONS THAT EMBODY TECHNOLOGY ISSUES OF ALL MISSIONS
- IDENTIFY & DEFINE CRITICAL CONSTRUCTION TECHNOLOGY ISSUES
- IDENTIFY WHICH TECHNOLOGY ISSUES CAN BE SOLVED ON GROUND
- DEFINE AN ORBITAL DEMONSTRATION/EQUIPMENT PROGRAM THAT RESOLVES THOSE TECHNOLOGY ISSUES THAT CANOT BE SOLVED ON GROUND

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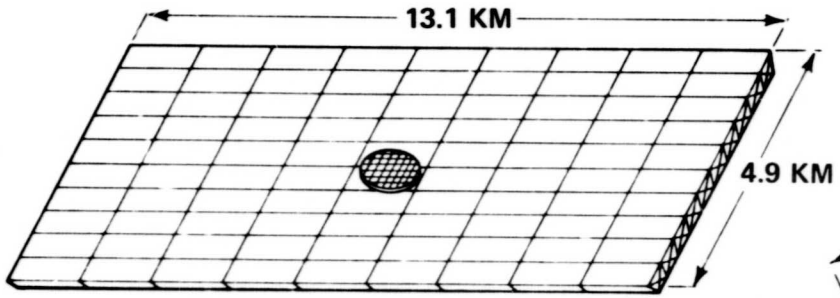
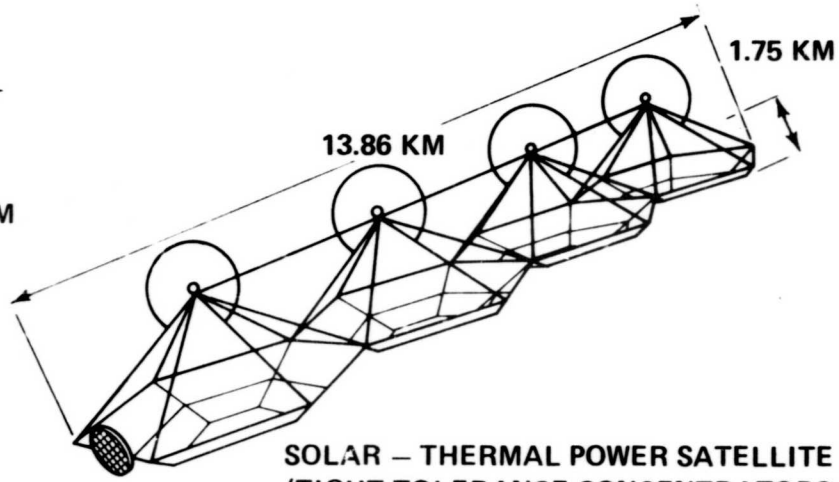
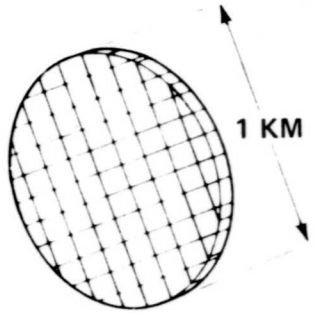
SELECTED REPRESENTATIVE STRUCTURES (THESE ENCOMPASS THE TECHNOLOGY REQMTS OF THE 40 STUDY MISSIONS)



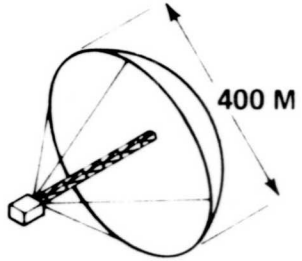
SOLAR POWER SATELLITE
(LARGE NEAR PLANAR ARRAY)



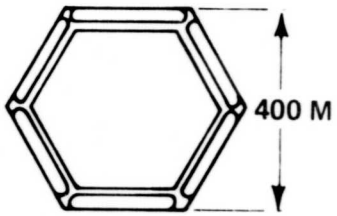
SOLAR – THERMAL POWER SATELLITE
(TIGHT TOLERANCE CONCENTRATORS
& LARGE RADIATORS)



MICROWAVE POWER
TRANSMISSION SYSTEM
(CRITICAL THERMAL
ENVIRONMENT/
PHASED ARRAY)



RADIOMETER
REFLECTOR
(COMPLEX FORM/
TIGHT TOLERANCE
SURFACE REQMT)



SOLAR MIRROR
(LARGE STRETCHED
MEMBRANE)

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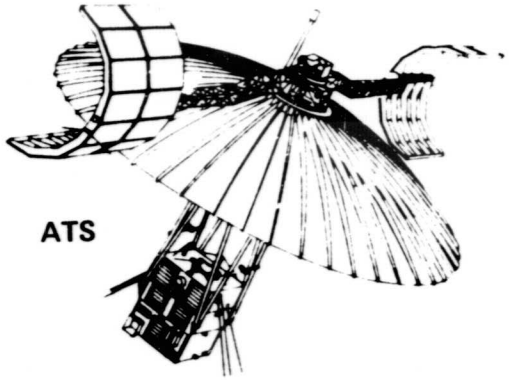
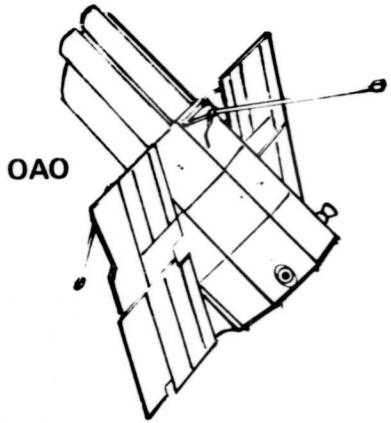
BASELINE STATE OF ART
(SOME TECHNOLOGY ISSUES HAVE ALREADY BEEN RESOLVED)

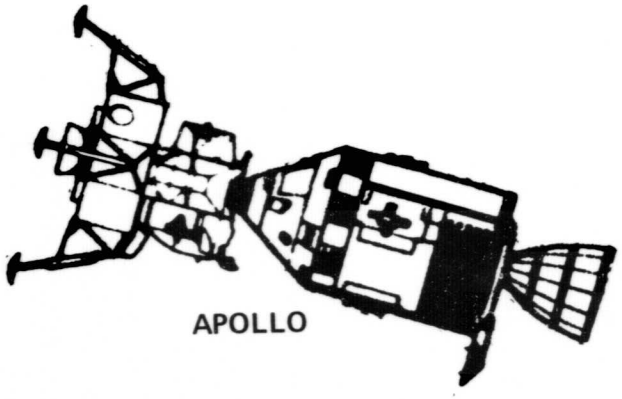


ATS

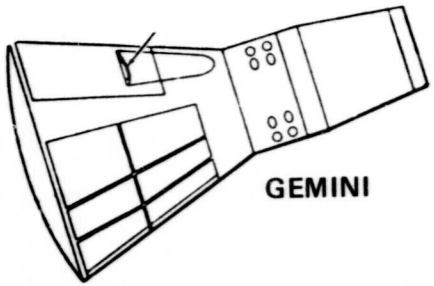
- DEPLOYMENT OF STRUCTURES
- DOCKING
- EVA REPAIR



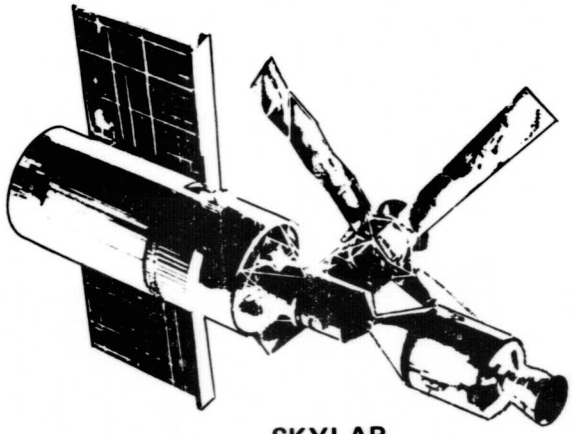
OAO



APOLLO



GEMINI



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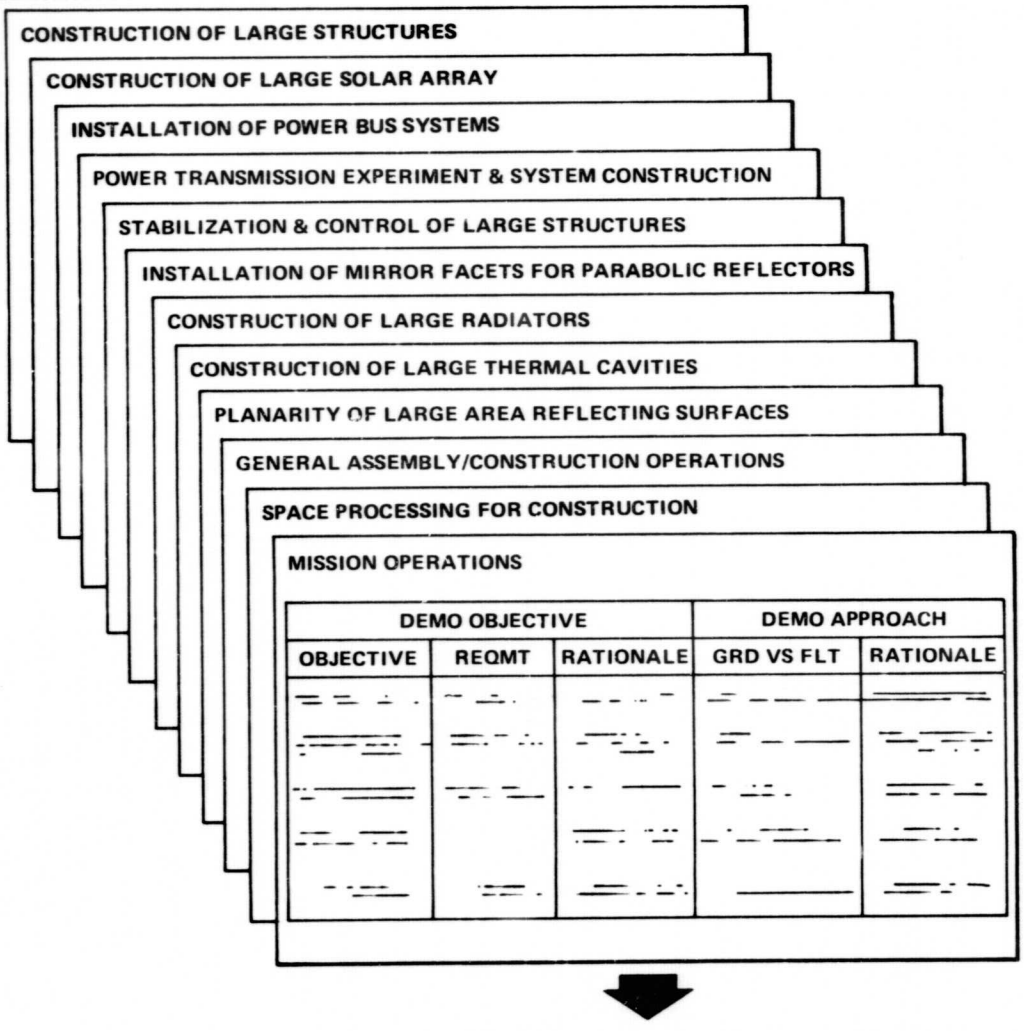
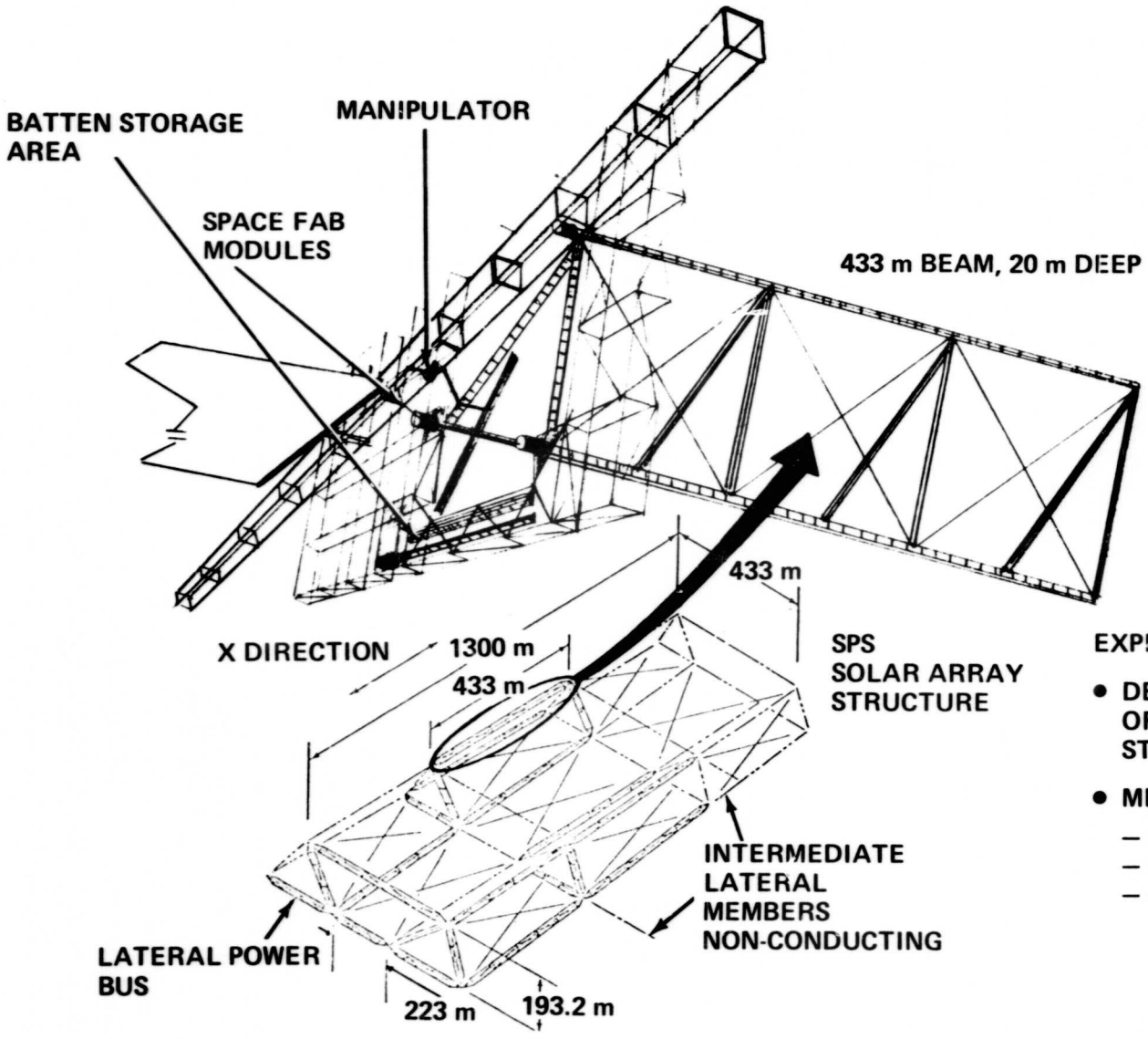
UNRESOLVED TECHNOLOGY ISSUES REQUIRING ORBIT DEMONSTRATION/TEST

CATEGORIES OF OBJECTIVES WERE DEVELOPED FROM THE FIVE REPRESENTATIVE STRUCTURES



72 EXPERIMENT OBJECTIVES/REQMTS DEFINED

FOLLOW-ON EXPERIMENT (20 M BEAM FABRICATION)



EXPERIMENT OBJECTIVES

- DEMONSTRATE PRODUCTION OF LARGE BUILDING BLOCK STRUCTURE
- MEASURE
  - PRODUCTIVITY
  - BEAM ALIGNMENT
  - JOINT INTEGRITY

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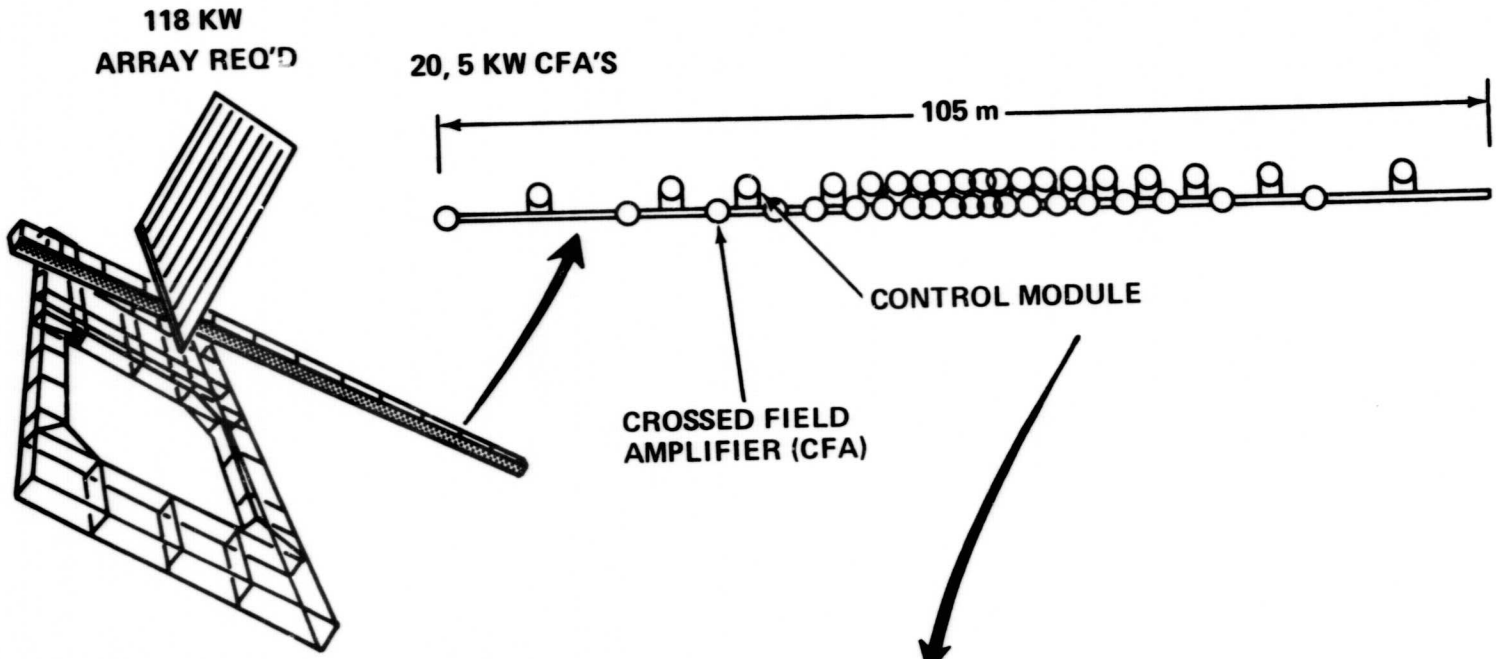
FOLLOW-ON EXPERIMENT (MICROWAVE LINEAR ARRAY)



OBJECTIVES

- PRODUCE POWER TAPERED SINGLE AXIS LINEAR ARRAY
- DEMONSTRATE/TEST EQUIPMENT PERFORMANCE & PHASE CONTROL
- 20 WAVEGUIDE SECTIONS TO SIMULATE ULTIMATE MPTS 10db TAPER POWER DENSITIES
- LINEAR ARRAY MOUNTED TO ROTATING BOOM WITH ACTIVE MECHANICAL CONTOUR CONTROL DEVICES

REQ'MT SOURCE: SPACE STATION SYSTEMS ANALYSIS STUDY (NAS 8-31993)

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PROGRAM OPTIONS TO ACCOMMODATE 72 OBJECTIVES

PROGRAM OPTION	DESCRIPTION	APPROX COST, $M	OBJECTIVES MET
1	BASIC CONSTRUCTION BASE WITH 250 KW SOLAR ARRAY	200 TO 400	29
2	OPTION 1 PLUS BUILDING OF 100 M RADIOMETER	425 TO 675	33
3	BASIC CONSTRUCTION BASE WITH 1 MW SOLAR ARRAY	375 TO 600	34
4	OPTION 3 PLUS BUILDING OF TRANSMISSION ANTENNA FOR SPS PROOF OF CONCEPT	570 TO 880	37

✔ SELECTED AS BASELINE OCDA PROG (CRITERIA - COST EFFECTIVENESS)

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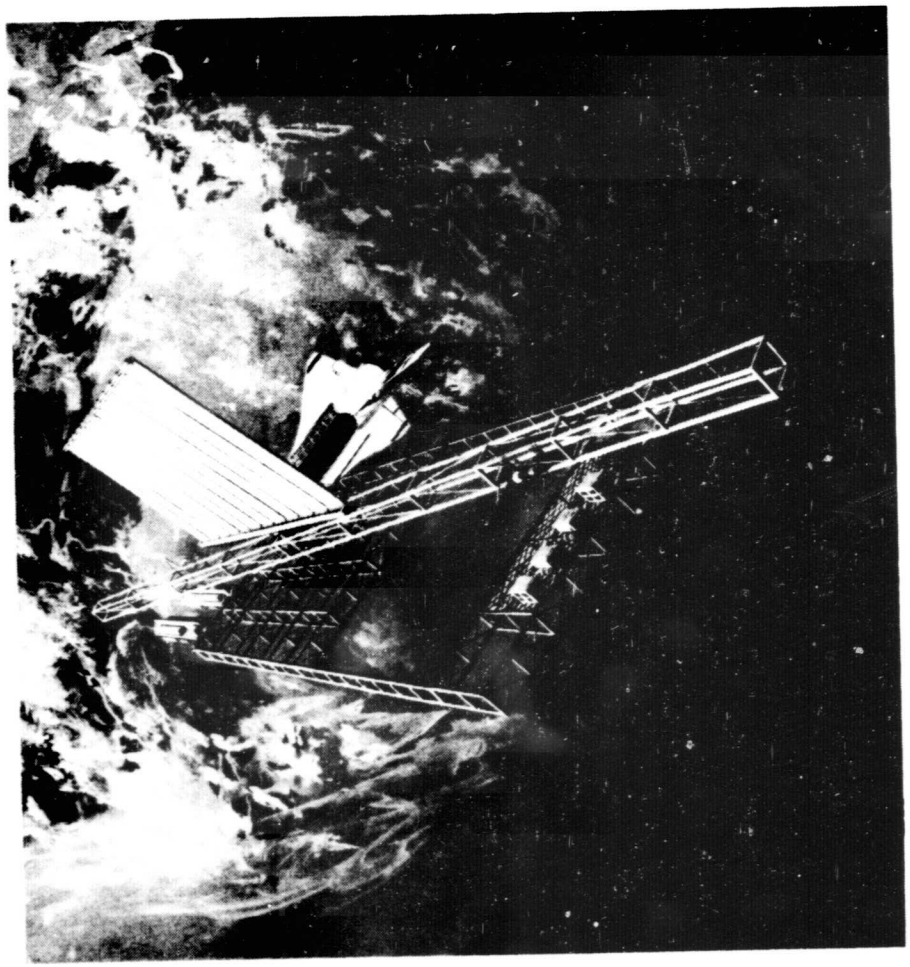
OPTION 1



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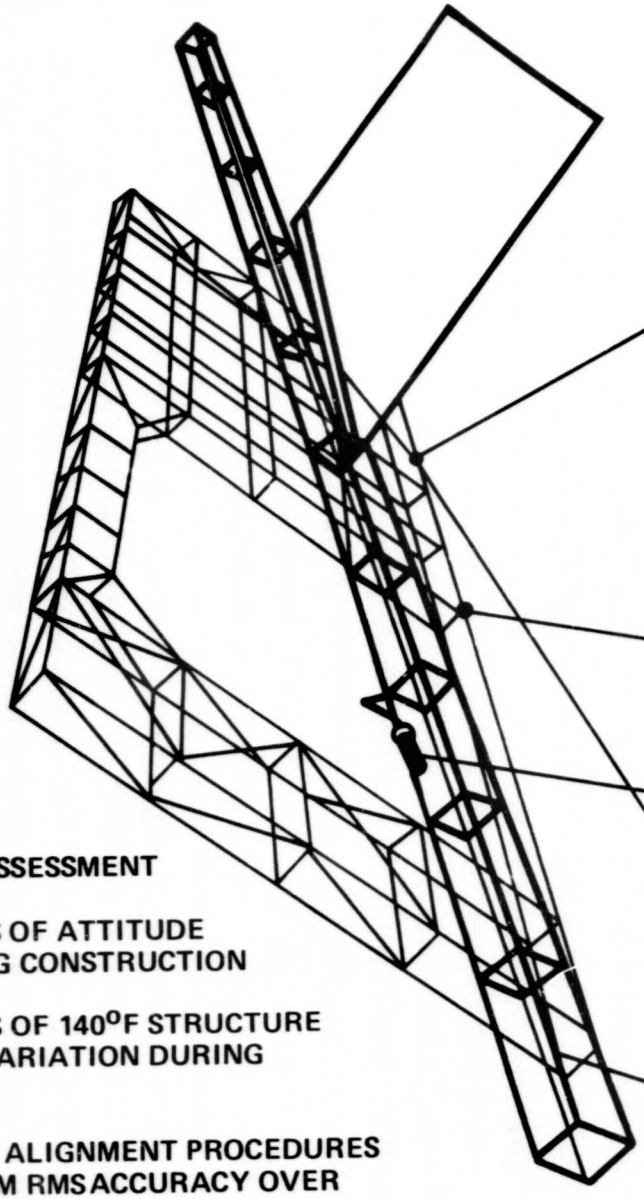
KEY LARGE STRUCTURES TECHNOLOGY OBJECTIVES MET WITH OCDA SELECTED FOR INITIAL DEPLOYMENT



LARGE STRUCTURES TECHNOLOGY

- FABRICATION AND/OR DEPLOYMENT OF STRUCTURAL BUILDING BLOCK BEAMS DEMONSTRATED BY HANDLING
  - 8 m BEAMS
  - 4 m BEAMS
  - 16 m BEAMS

  BOTH ALUMINUM & COMPOSITES
- JOINT ASSEMBLY PROCEDURES: DEMONSTRATED WITH OVER 100 JOINING OPERATIONS USING CENTROIDAL & BUTT TYPE FITTINGS
- MAN/MACHINE INTERACTION DEMONSTRATED WITH MANIPULATOR MODULE
- LARGE ELEMENT MATING DEMONSTRATED WITH INSTALLATION OF SOLAR BLANKET SECTIONS
- SECONDARY STRUCTURE INSTALLATION DEMONSTRATED BY ASSEMBLY OF RAIL SYSTEM, AND POWER BUS

- FIRST CUT AT PRODUCTIVITY ASSESSMENT
- FACES PROBLEMS OF ATTITUDE CONTROL DURING CONSTRUCTION
- FACES PROBLEMS OF 140°F STRUCTURE TEMPERATURE VARIATION DURING CONSTRUCTION
- FACES ISSUES OF ALIGNMENT PROCEDURES TO ACHIEVE 10 CM RMS ACCURACY OVER PLATFORM SURFACE

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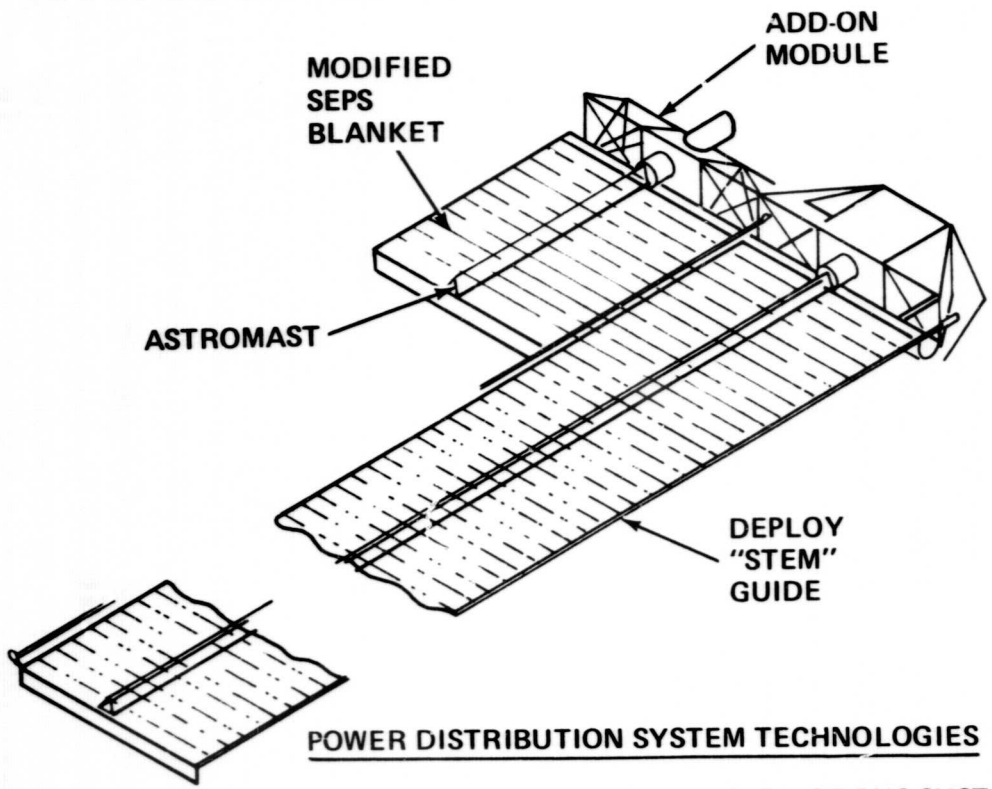
KEY LARGE SOLAR ARRAY & POWER DISTRIBUTION SYSTEM TECHNOLOGY OBJECTIVES MET WITH OCDA SELECTED FOR INITIAL DEPLOYMENT



LARGE SOLAR ARRAY TECHNOLOGIES

- DEMONSTRATES ONE METHOD TO DEPLOY LARGE AREAS OF SOLAR BLANKET.
- DEMONSTRATES BLANKET INTERFACE WITH STRUCTURE, POWER BUS AND MONITOR/COMMAND SYSTEMS
- ADDRESSES ISSUES OF C/O AND FAULT ISOLATION
- COULD BE CONFIGURED TO OPERATE AT 20KV TO ADDRESS HI VOLTAGE ISSUES
- ADDRESSES THERMAL CYCLING ISSUES

POWER DISTRIBUTION SYSTEM TECHNOLOGIES

- DEMONSTRATES INSTALLATION OF BUS SYSTEM INCLUDING CONDUCTORS, POWER CONDITIONERS AND SWITCH GEAR
- ADDRESSES ISSUES OF ENERGY STORAGE FOR ATTITUDE CONTROL, SYSTEM HEATING, ETC.
- ADDRESSES ISSUES OF LARGE ROTARY JOINT INSTALLATION AND OPERATION
- ADDRESSES ISSUES OF C/O, FAULT ISOLATION & REPAIR

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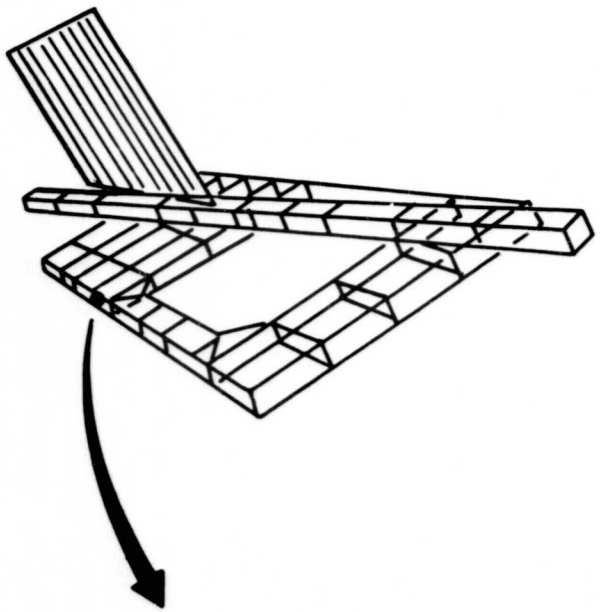
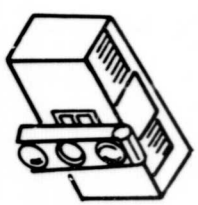
KEY PROPULSION & STABILIZATION TECHNOLOGY OBJECTIVES MET WITH OCDA SELECTED FOR INITIAL DEPLOYMENT





ION ENGINE FOR STATIONKEEPING

– 30 CM THRUSTERS

PROPULSION TECHNOLOGIES

- DEMONSTRATES ON ORBIT INSTALLATION OF LOW THRUST PROPULSION SYSTEMS FOR ORBIT KEEPING & ATTITUDE CONTROL
- ADDRESSES ISSUES OF PROPELLANT RESUPPLY
- ADDRESSES ISSUES OF EXHAUST CONTAMINATION OF SOLAR ARRAY

STABILIZATION & CONTROL

- ADDRESSES ISSUE OF CONTROL OF LARGE FLEXIBLE STRUCTURE
  - LOCATION OF SENSORS & ACTUATORS
- ADDRESSES CONTROL ISSUES OF CONFIGURATIONS WITH CHANGING GEOMETRY DURING CONSTRUCTION & DURING OPERATIONS
- ADDRESSES DESIGN ISSUES OF ROTARY JOINT CONTROL & ACCURACY

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SUBSEQUENT USAGE OF OCDA BEYOND INITIAL DEPLOYMENT (MEETING ADDITIONAL OBJECTIVES)

TYPICAL FOLLOW-ON EXPERIMENTS

- **20 M BEAM FABRICATION**
- **MICROWAVE LINEAR ARRAY**
- **ETC.**

ADD-ON STUDY REQUIRED TO ADDRESS DEFINITION OF FOLLOW-ON EXPERIMENTS

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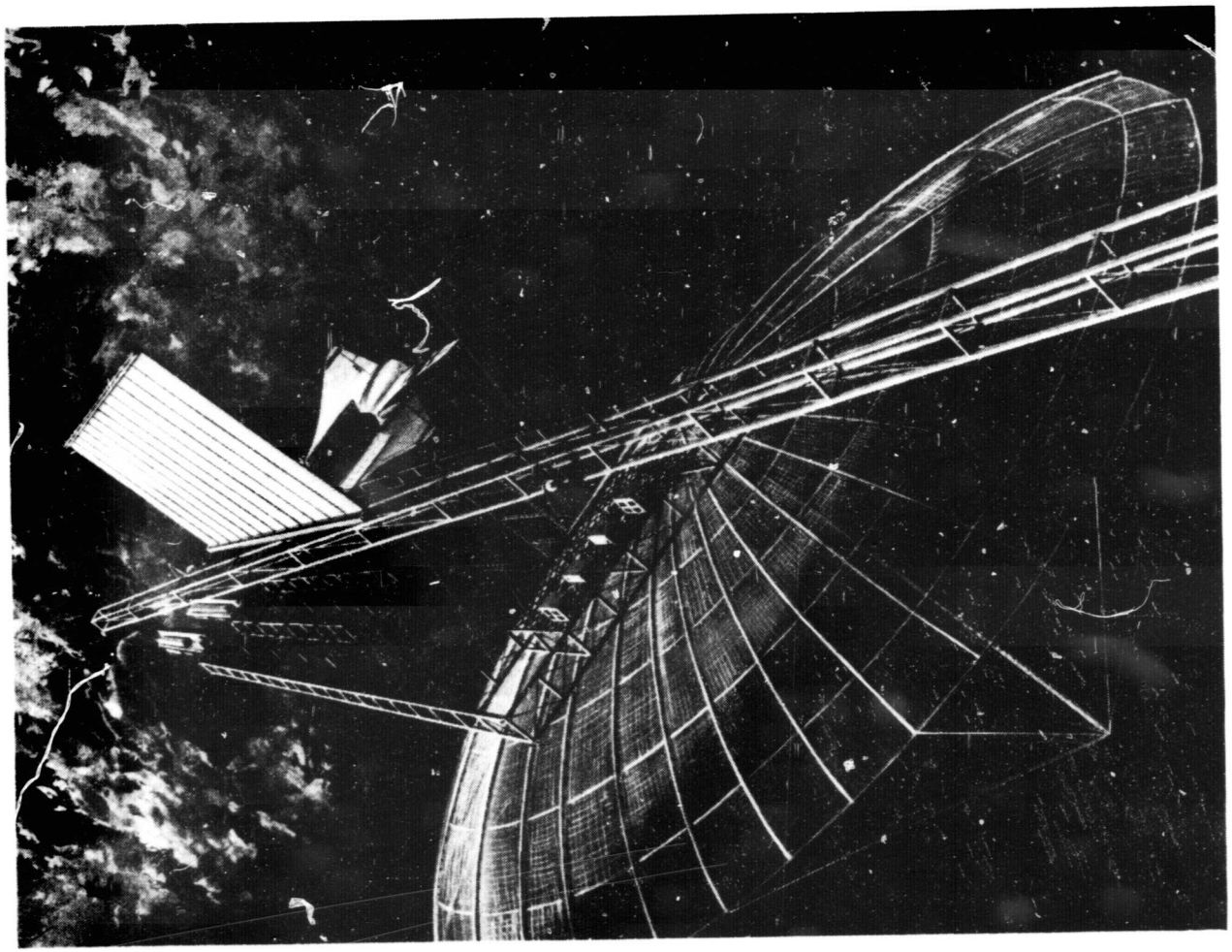
TYPICAL OPERATIONAL USAGE (OPTION 2)



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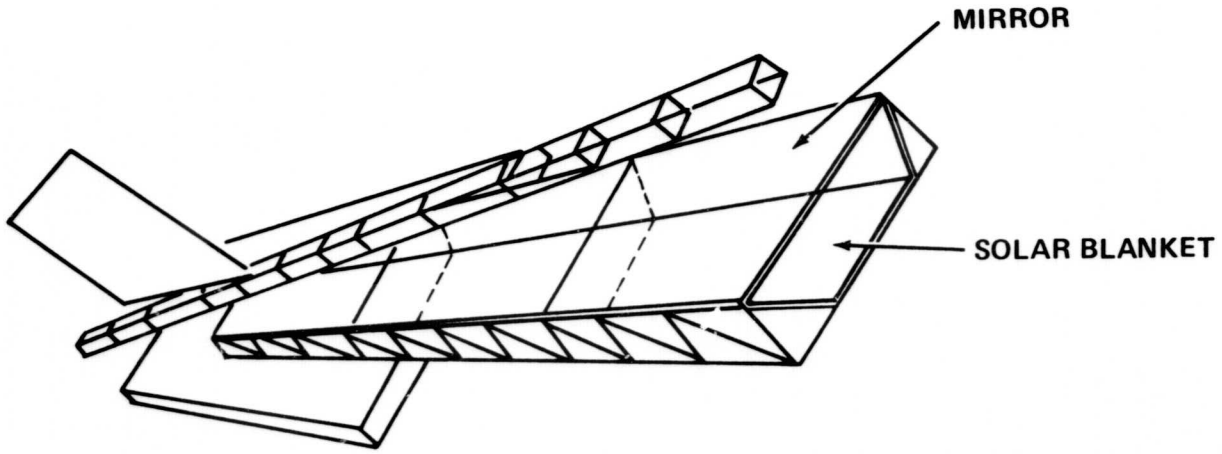
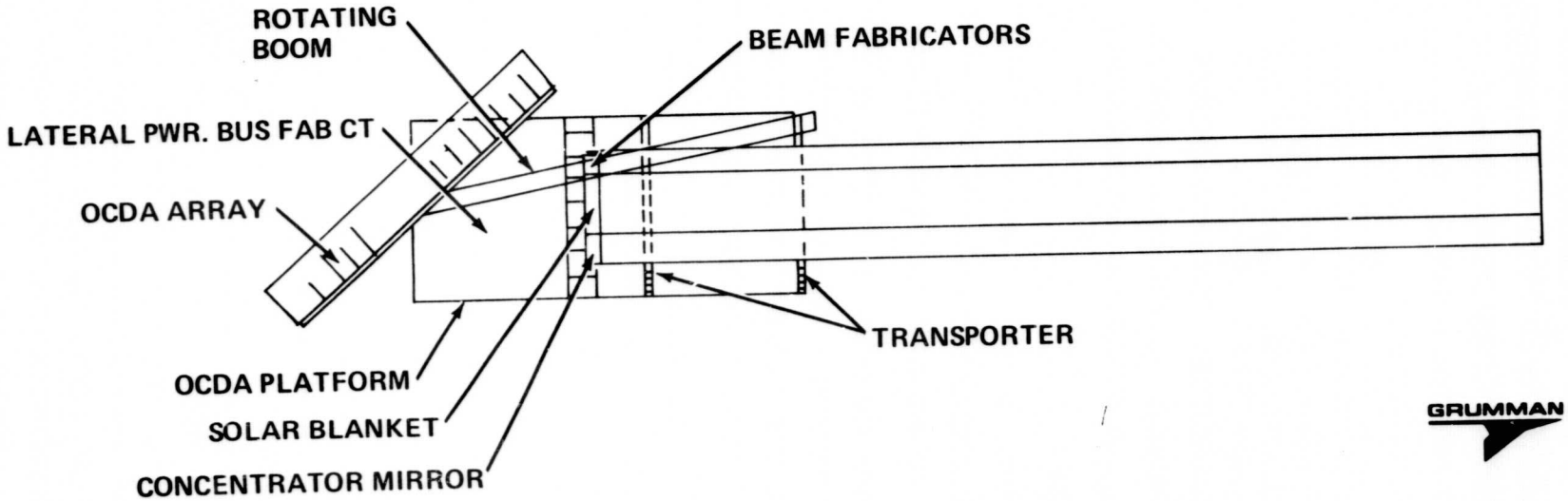
TYPICAL OPERATIONAL USAGE – CONSTRUCTION OF LARGE SOLAR ARRAY (OPTION 3)





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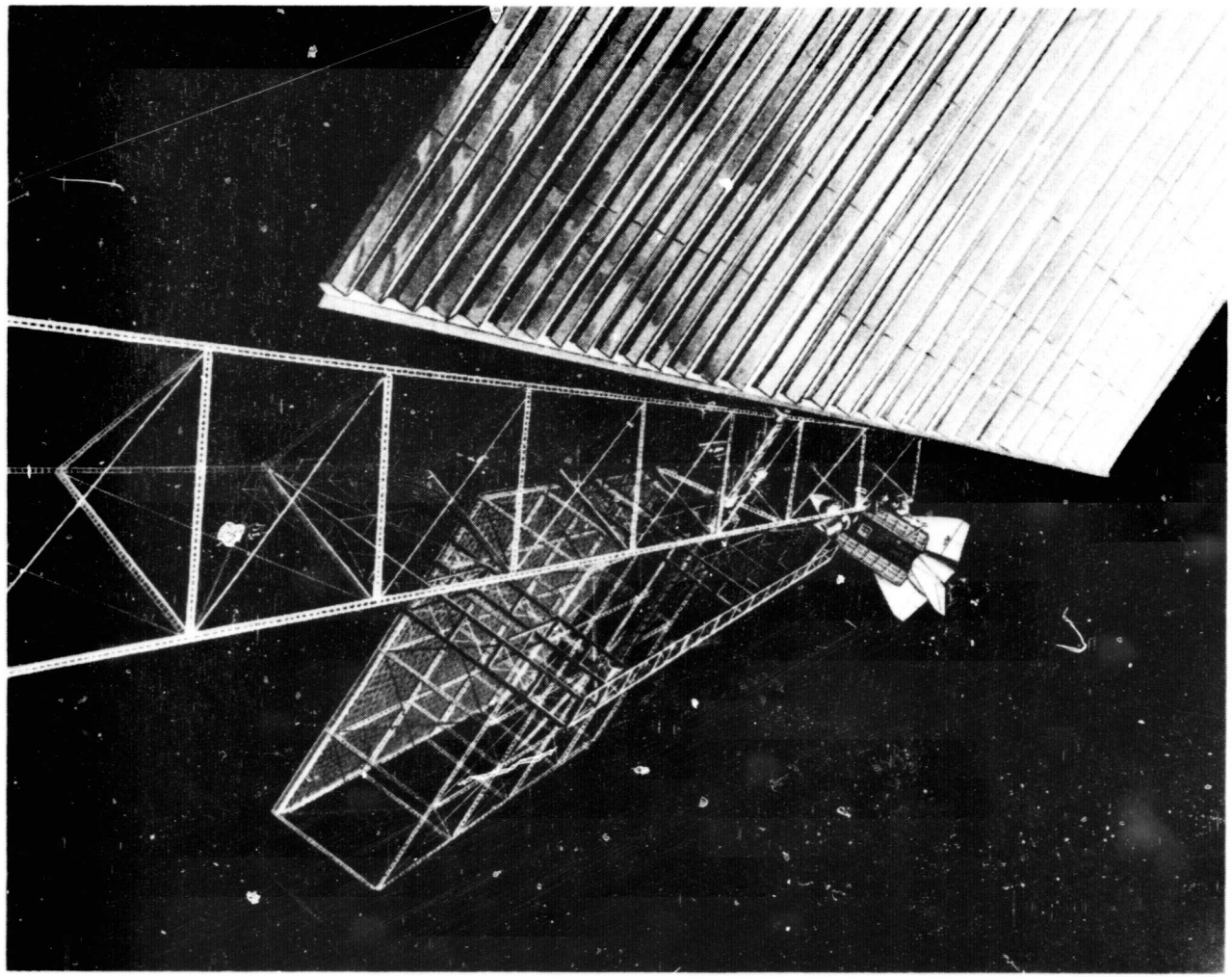
TYPICAL OPERATIONAL USAGE (OPTION 4)



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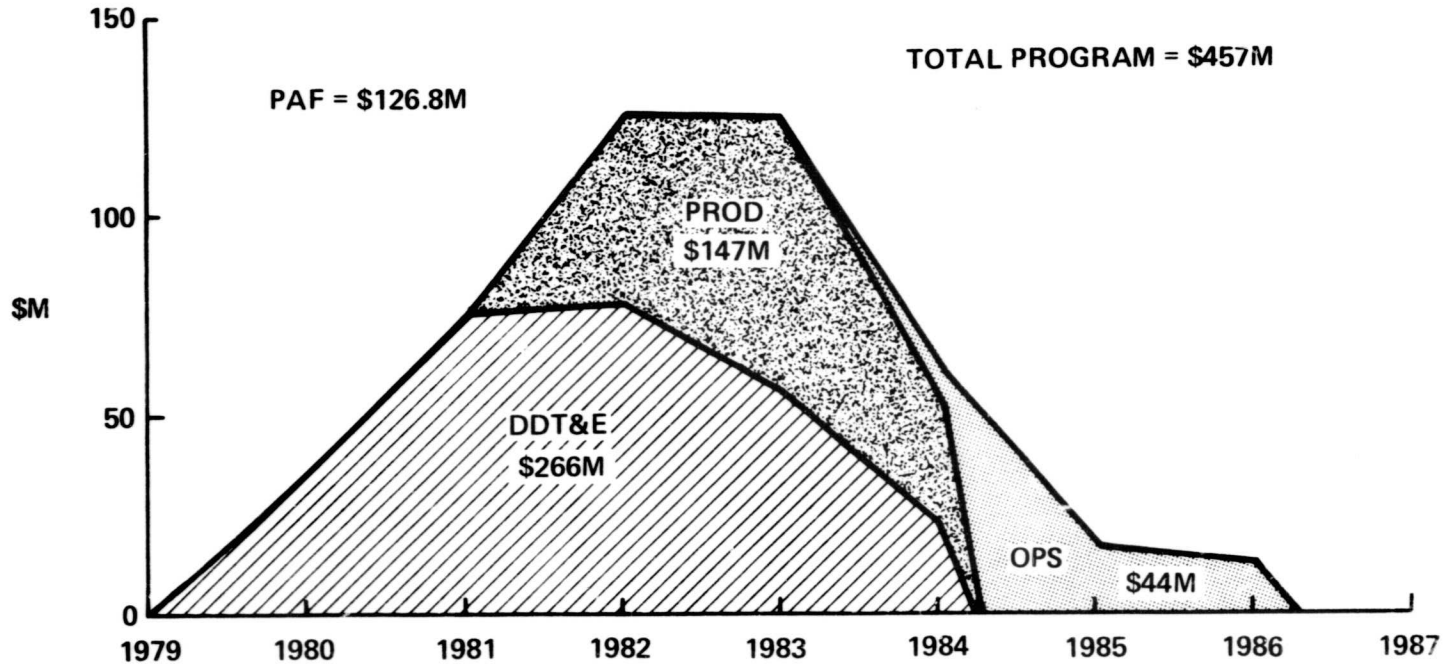
COST OF SELECTED OCDA



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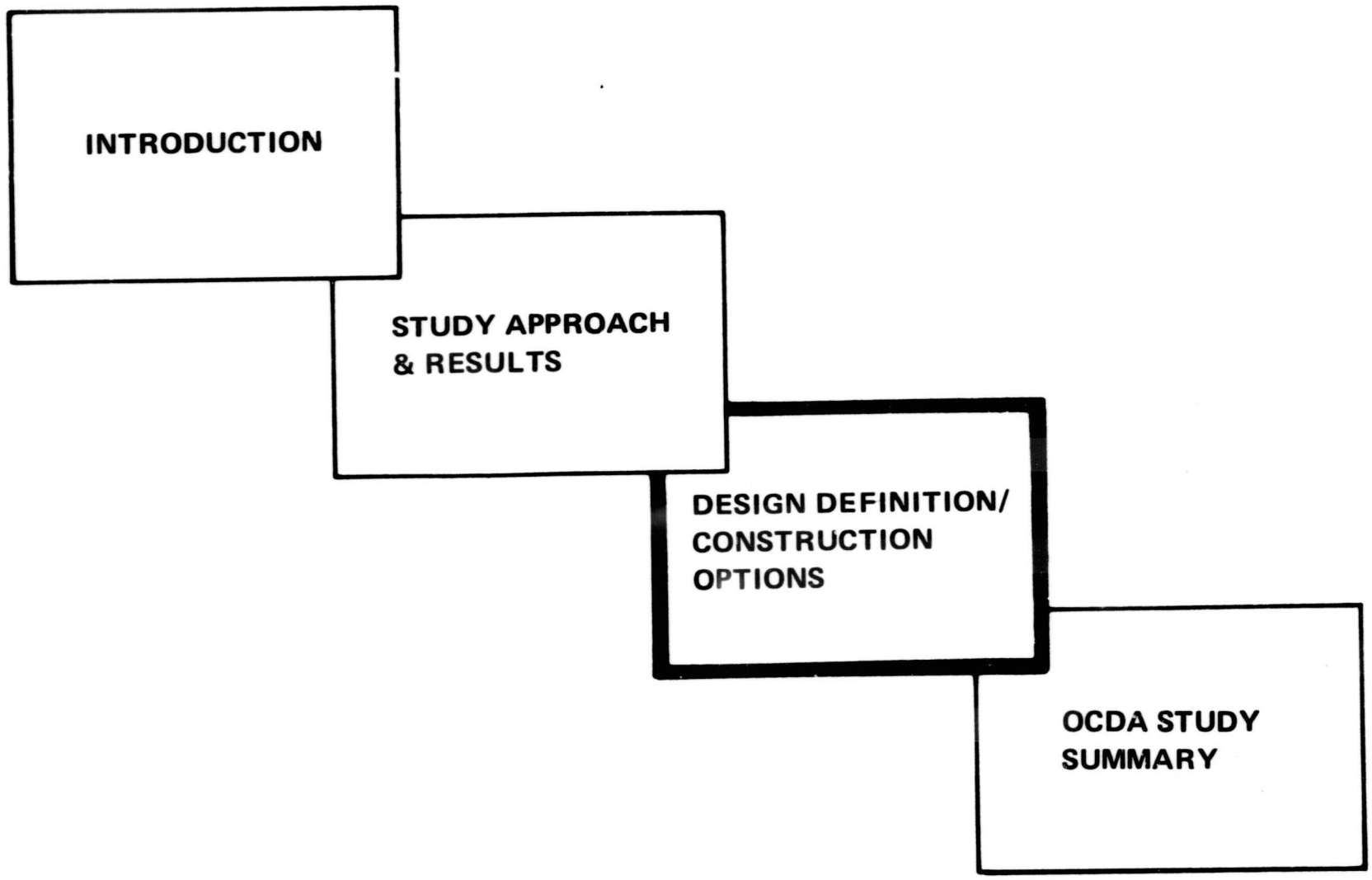

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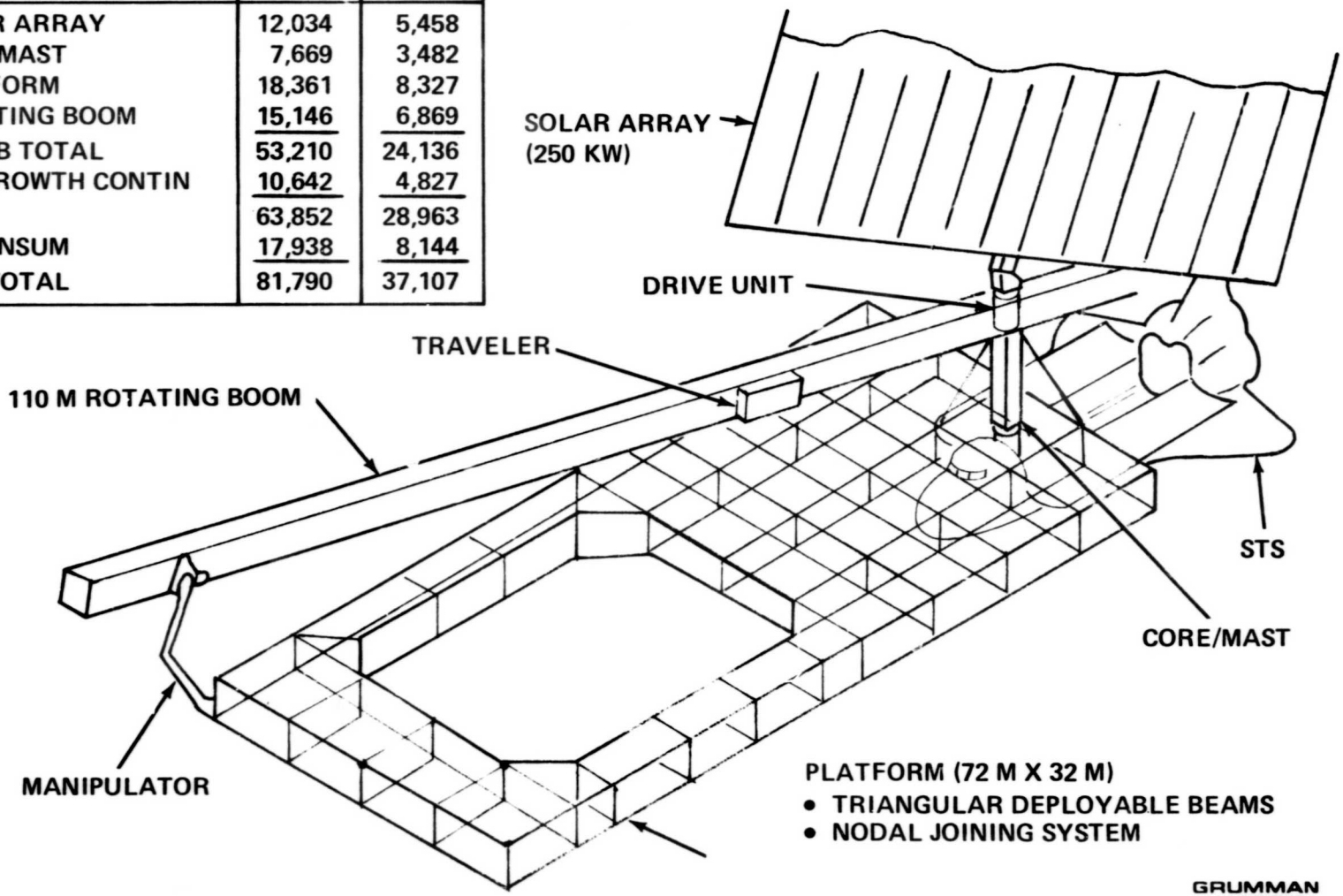
SELECTED OCDA – DESIGN DEFINITION

	MASS	
	LBM	KG
• SOLAR ARRAY	12,034	5,458
• CORE MAST	7,669	3,482
• PLATFORM	18,361	8,327
• ROTATING BOOM	15,146	6,869
SUB TOTAL	53,210	24,136
20% GROWTH CONTIN	10,642	4,827
	63,852	28,963
CONSUM	17,938	8,144
TOTAL	81,790	37,107



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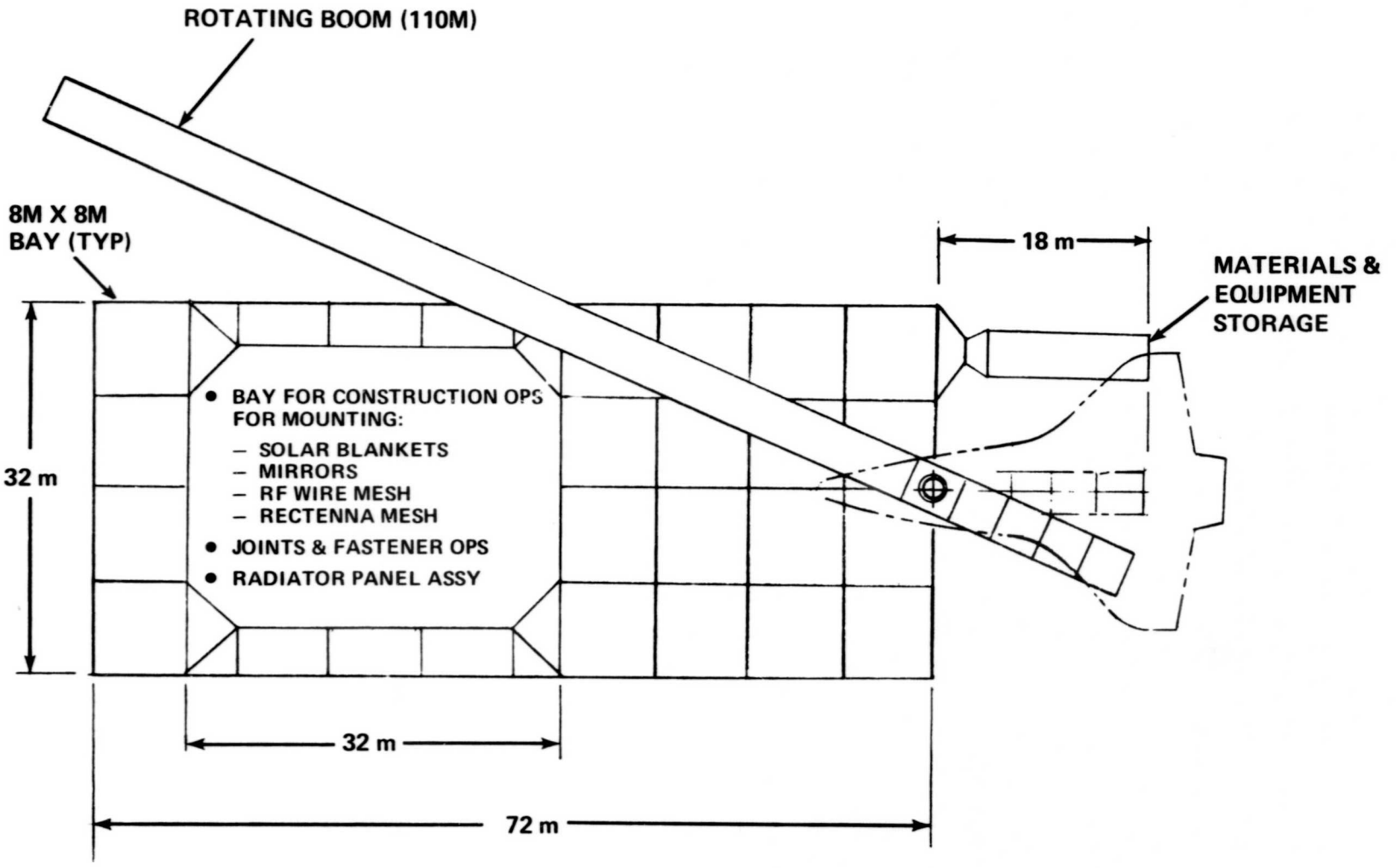
SELECTED OCDA – USE AS A GENERAL PURPOSE DEMO/TEST FACILITY FOR CONSTRUCTION TECHNOLOGY



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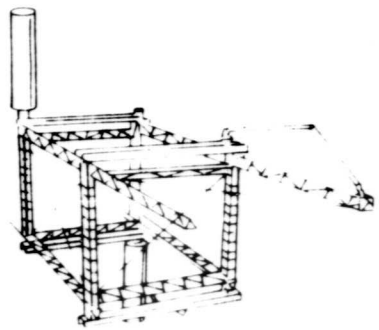
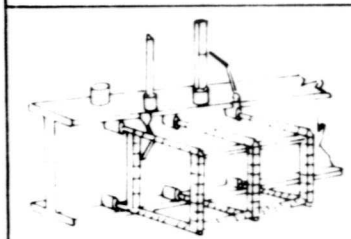
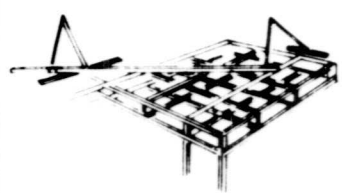
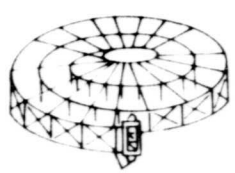
GUIDELINES USED FOR SELECTION OF ASSEMBLY TECHNIQUES FOR INITIAL OCDA DEPLOYMENT

OPTION	
	I POST WALKER
	II CONSTRUCTION JIG
	III LONG BOOM
	IV SPIRAL FABRICATOR

DERIVED FROM STUDY OF FUTURE MISSIONS

OCDA INITIAL DEPLOYMENT SHOULD:

- EMPHASIZE PARALLEL CONSTRUCTION OPERATIONS WHERE POSSIBLE
- USE CREW TO:
  - MONITOR
  - CORRECT MALFUNCTIONS
  - PERFORM UNIQUE TASKS
- CONSIDER MATERIALS LOGISTICS SYSTEM TO BE ATTACHED TO BASE (AS OPPOSED TO FREE FLYERS)
- CENTRALLY LOCATE FABRICATION EQUIPMENTS
- GROUND MANUFACTURE COMPLEX COMPONENTS

GRUMMAN

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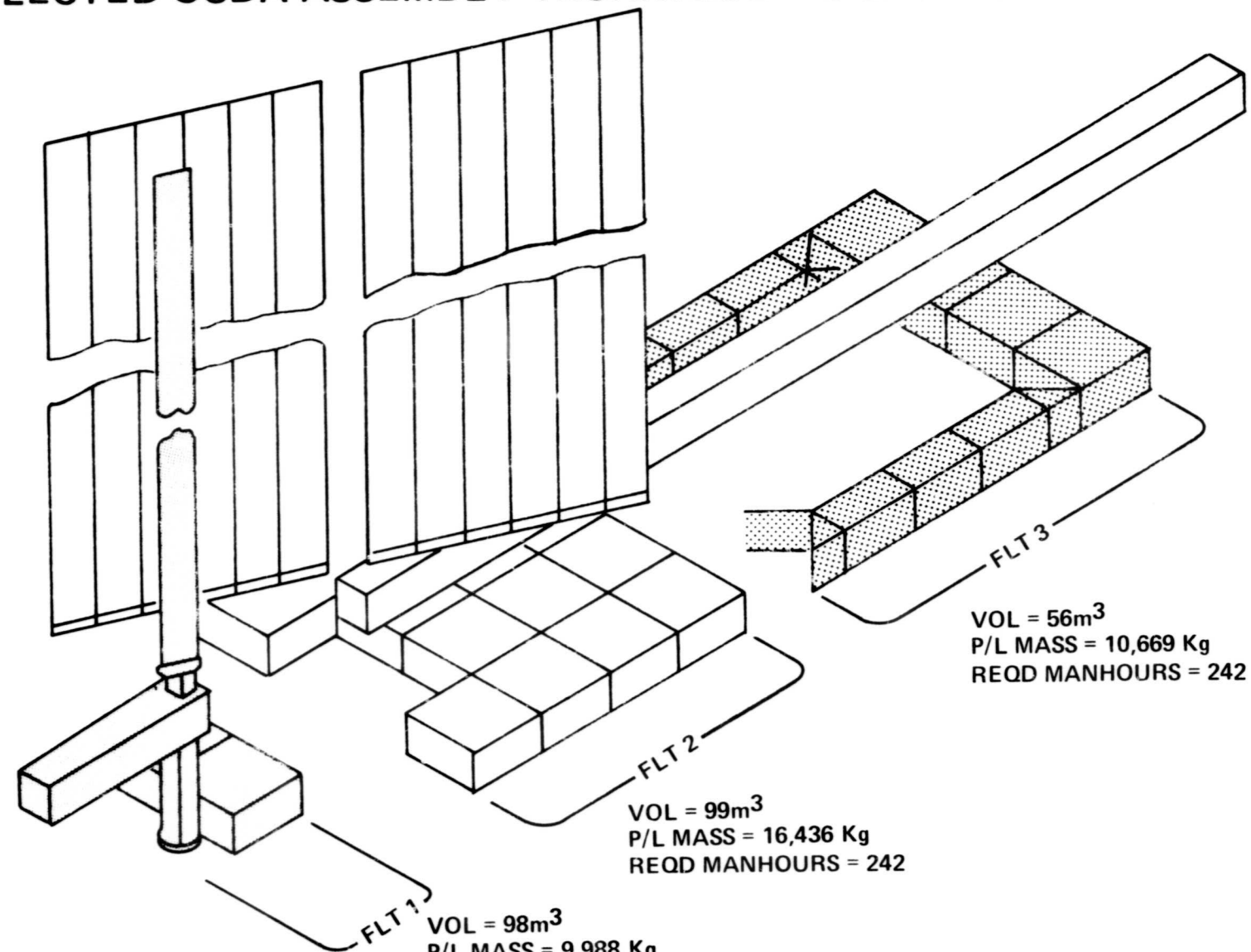
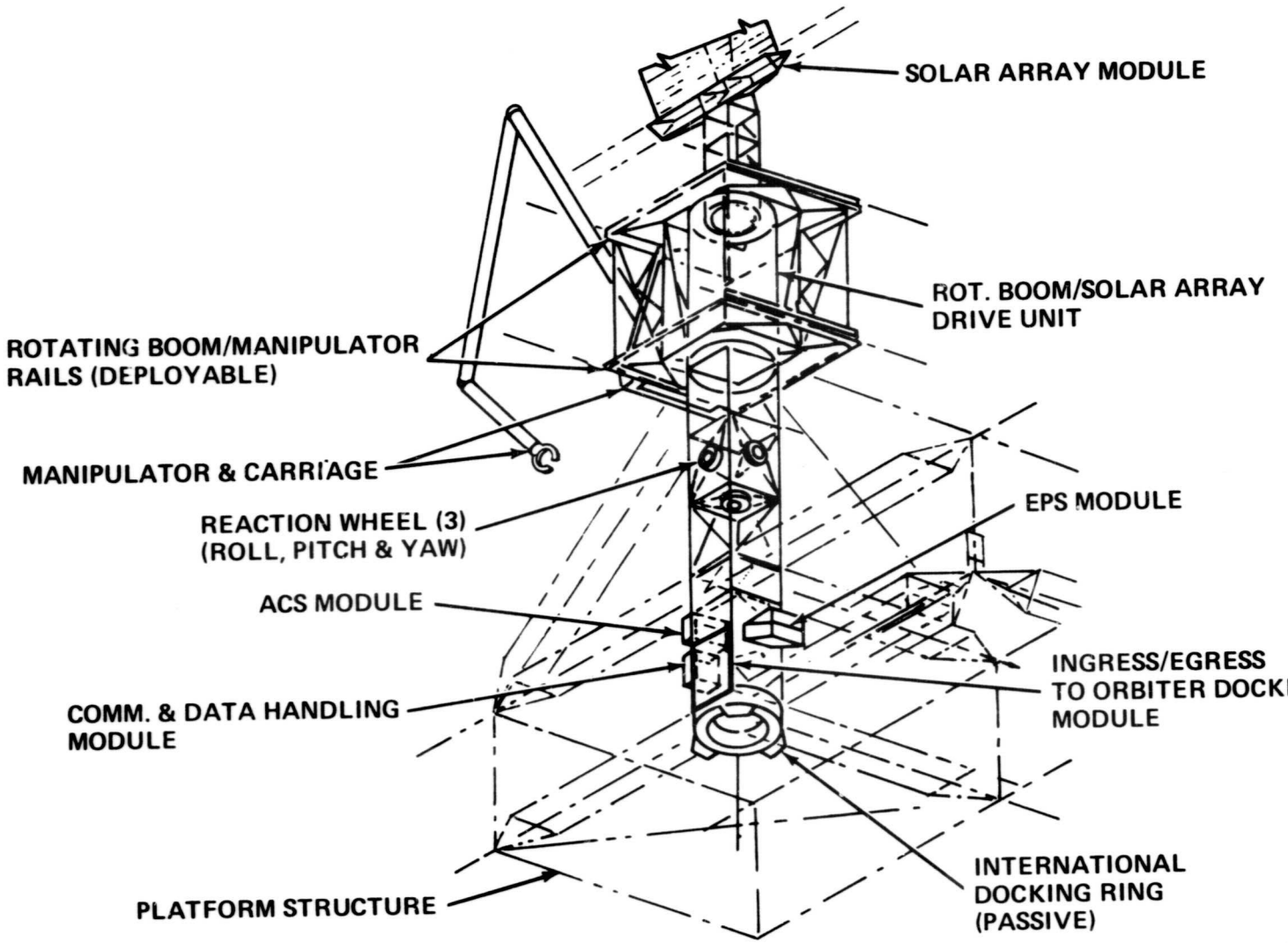
SELECTED OCDA ASSEMBLY TECHNIQUE – 3 SHUTTLE FLIGHTS



GRUMMAN

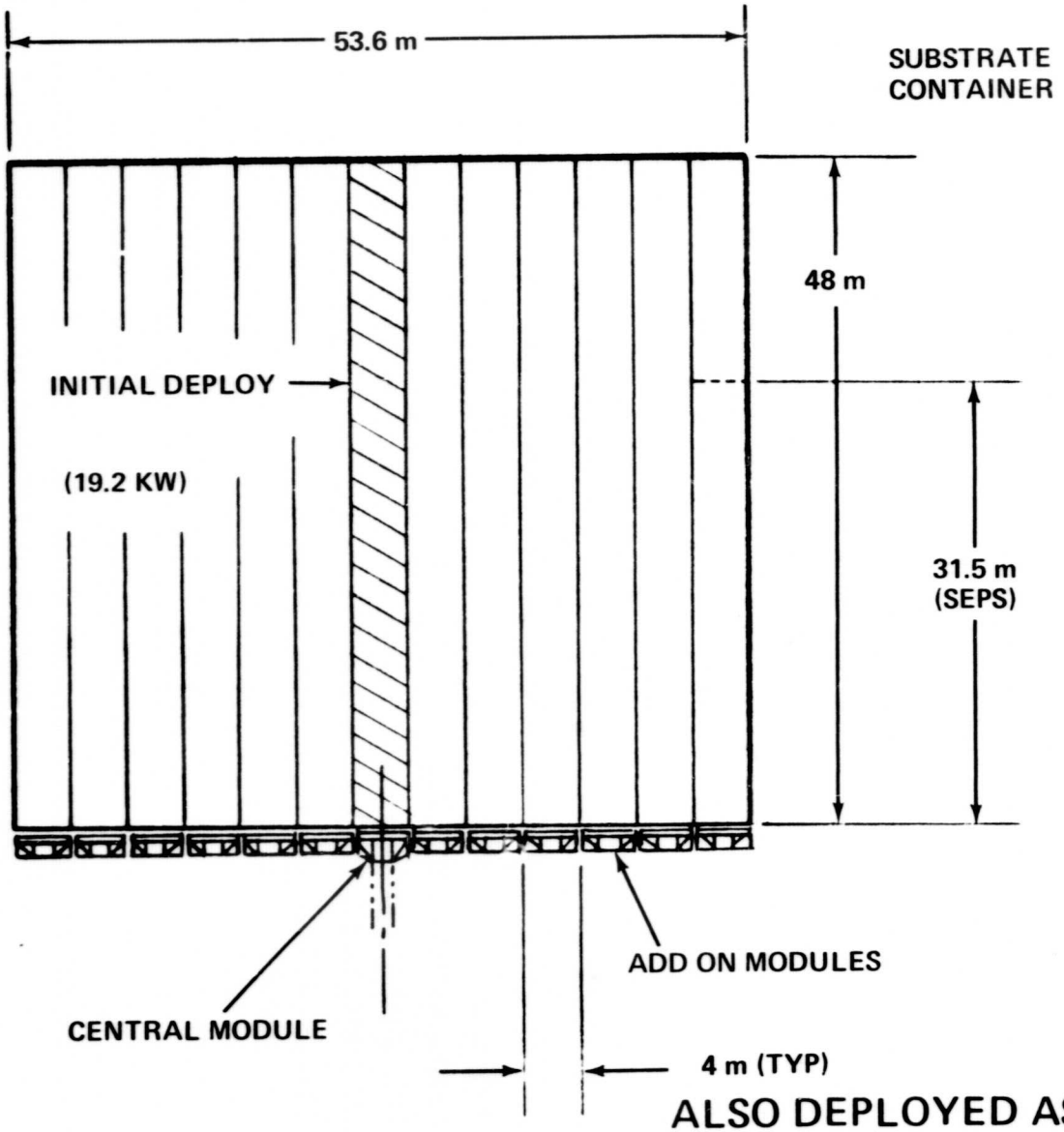
OCDA CORE MODULE/MAST CONFIGURATION DETAIL DESIGN

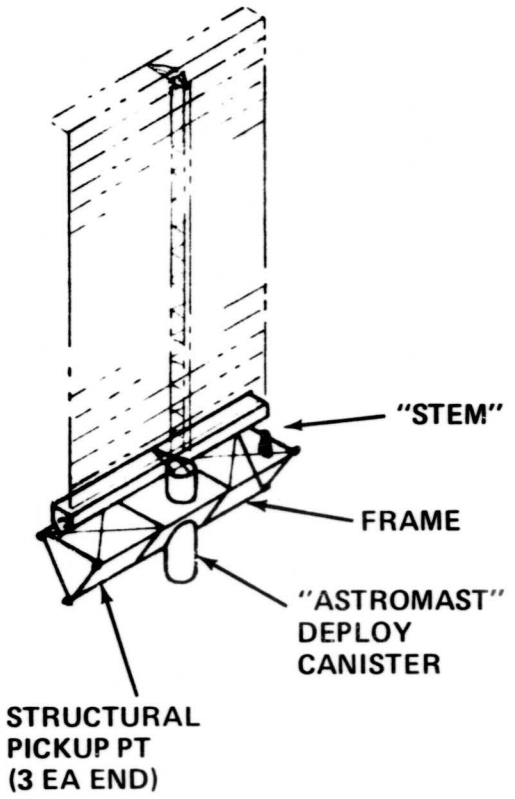


DEPLOYED AS A UNIT

GRUMMAN

OCDA – SOLAR ARRAY (250 KW) – DETAIL DESIGN





TYPICAL SOLAR ARRAY MODULE

ALSO DEPLOYED AS A UNIT

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SELECTED PLATFORM CONSTRUCTION TECHNIQUES

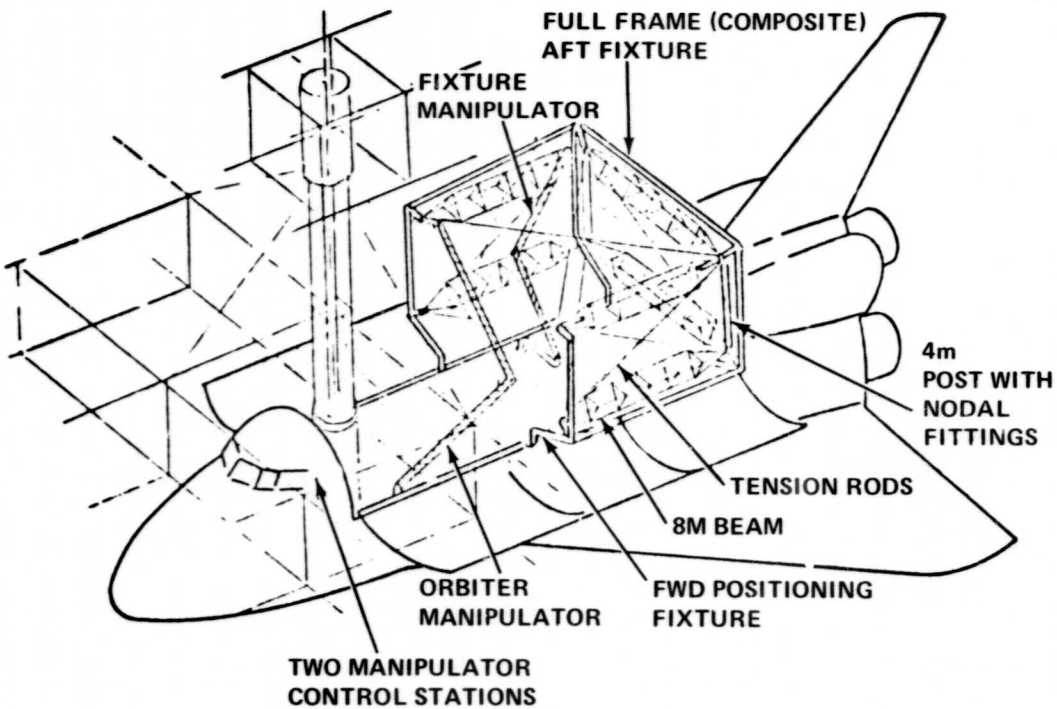
EMPHASIZES:

- PARALLEL ASSEMBLY OPERATIONS
- CENTRALIZED STRUCTURAL FABRICATION

TYPICAL STUDY TREATMENT OF CONSTRUCTION OPERATION

ASSEMBLE 3/4 CUBE (13 TIMES)

TASKS	TIME, MIN
EXTRACT POST (ORB MANIP)	2
INSTALL IN FIXTURE (ORB MANIP.)	4
REPEAT ABOVE	6
EXTRACT FOLDED BEAM (ORB MANIP.)	3
PLUG INTO DEPLOYMENT STATION & DEPLOY	4
TRANSPORT BEAM TO FIXTURE (ORB MANIP.)	3
ATTACH BEAM (FIX MANIP.)	6
REPEAT ABOVE 5 TIMES	80
INSTALL HANDLING BEAM	6
ATTACH STAYS (10)	60
TENSION STAYS (2)	6
TOTAL	3 HR



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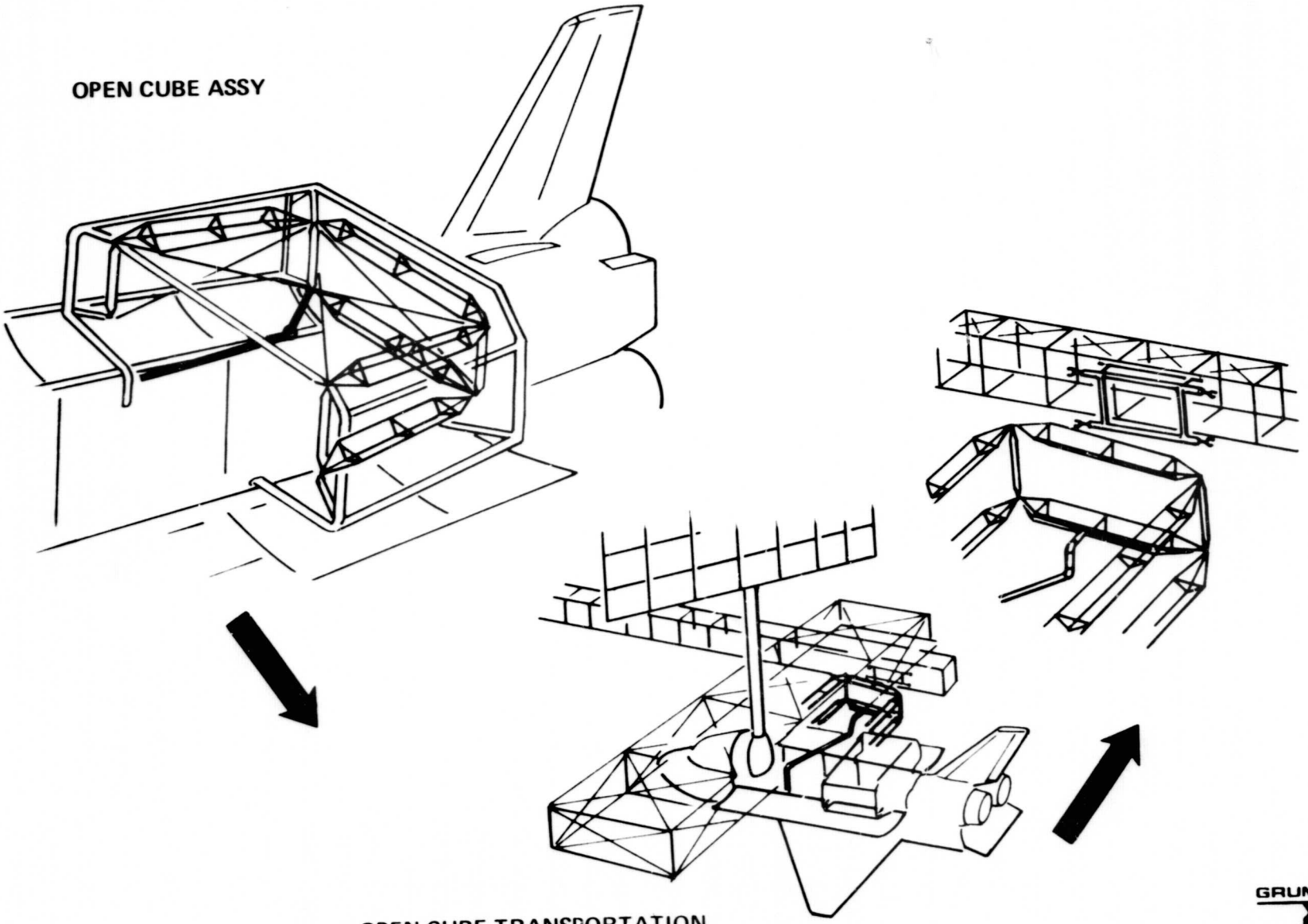
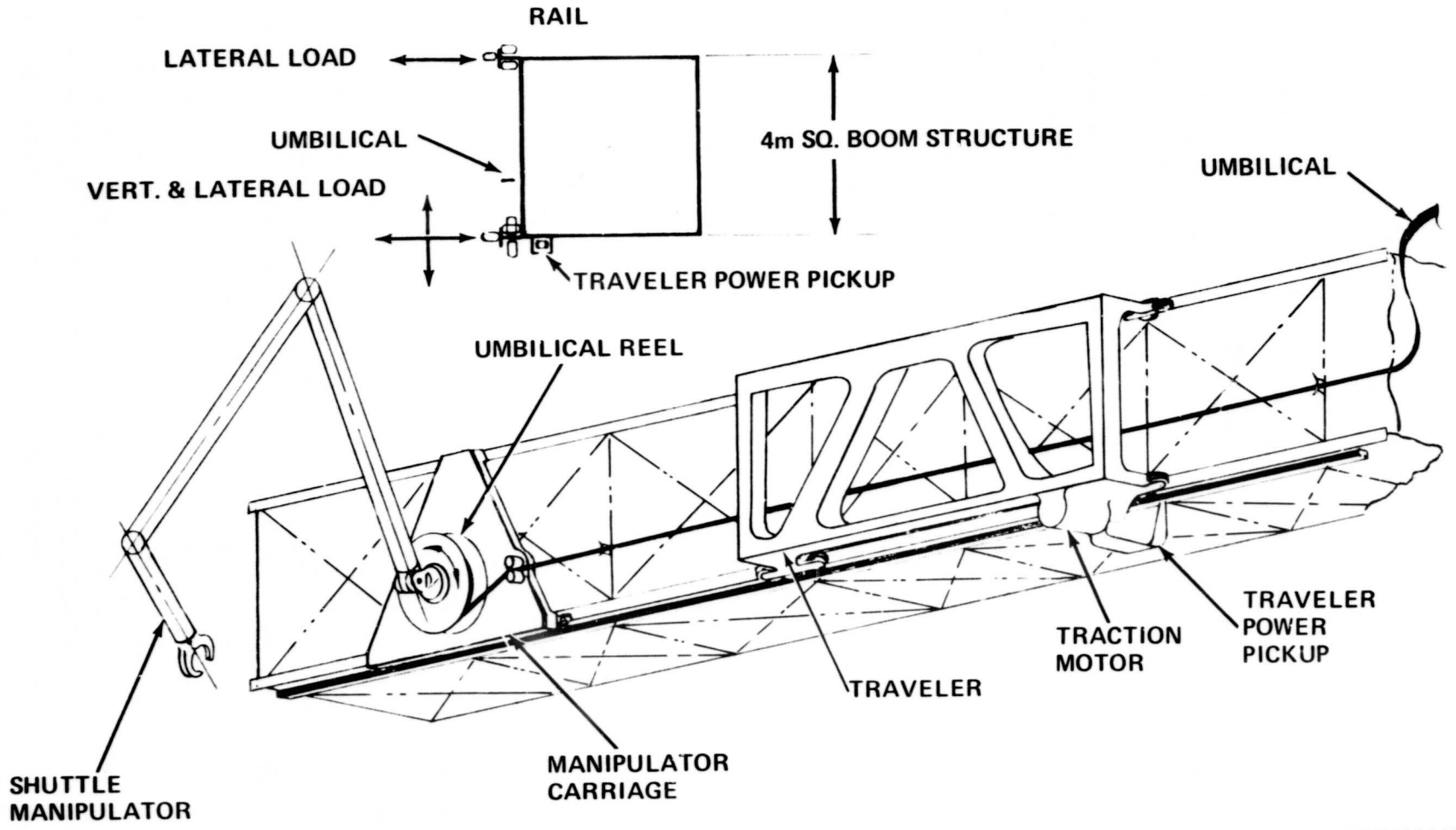
OCDA PLATFORM CONSTRUCTION SEQUENCE



OCDA ROTATING BOOM/MANIPULATOR AND TRAVELER DESIGN



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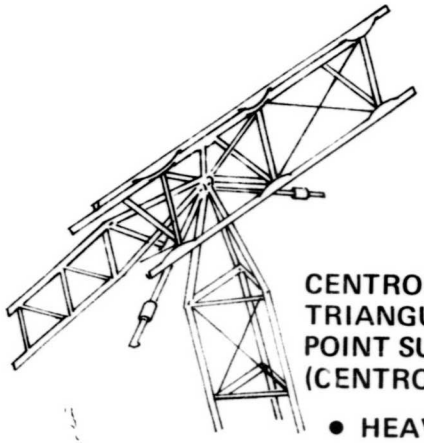
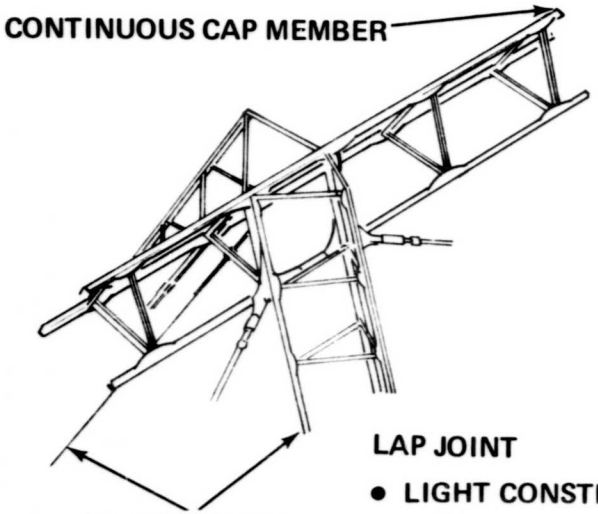
SELECTED JOINT & FASTENER TECHNIQUES



CENTROIDAL JOINT WITH ONE CONTINUOUS TRIANGULAR BEAM & 2 SINGLE POINT SUPPORT POSTS (CENTROIDAL)

- HEAVIER
- BETTER ACCESS
- EASIER ALIGNMENT

√ SELECTED FOR BASIC OCDA



LAP JOINT

- LIGHT CONSTRUCTION
- TIME CONSUMING JOINT
- DIFFICULT ACCESS & ALIGN

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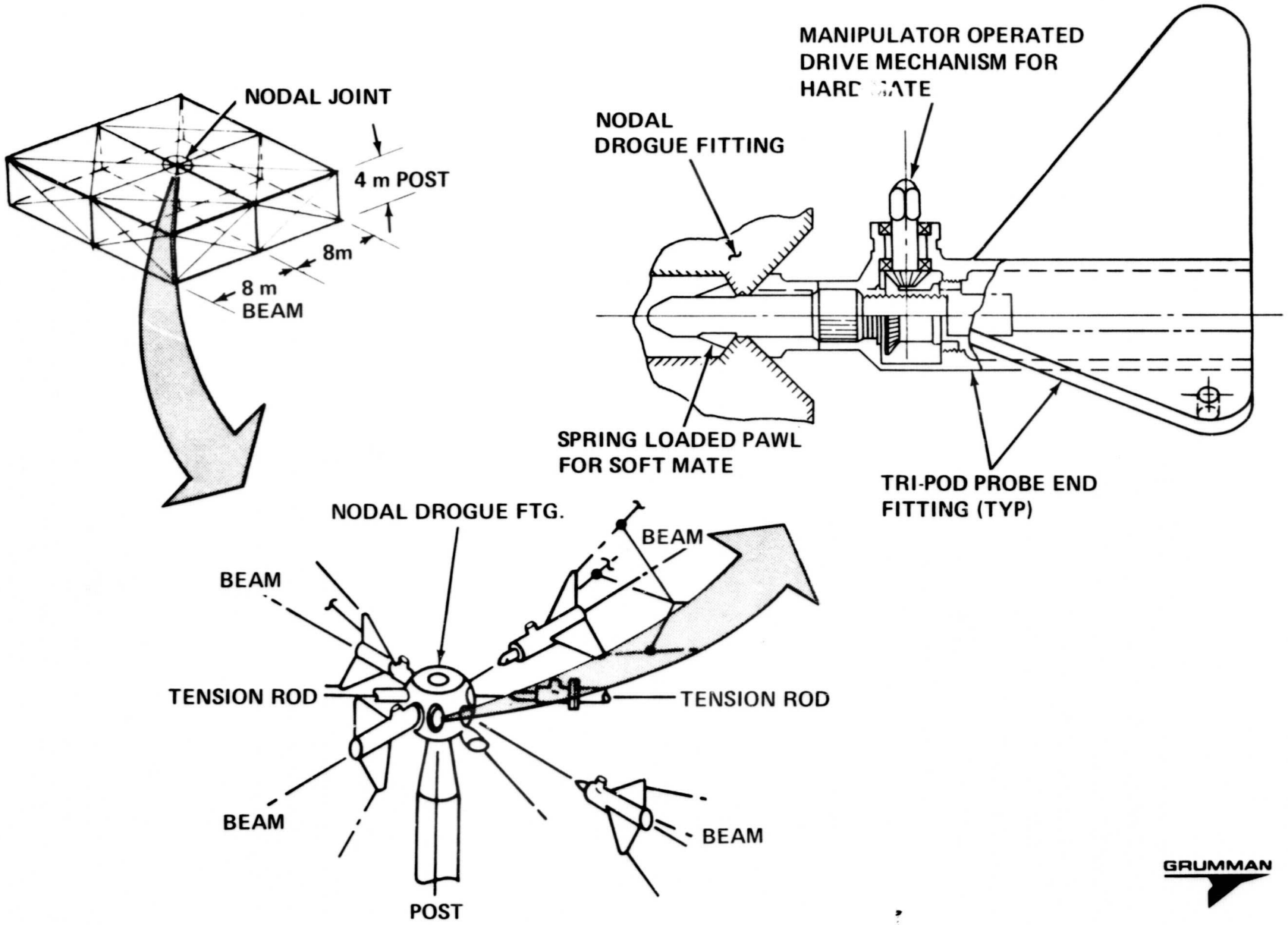
OCDA PLATFORM JOINING SYSTEM (CENTROIDAL FITTING) DESIGN



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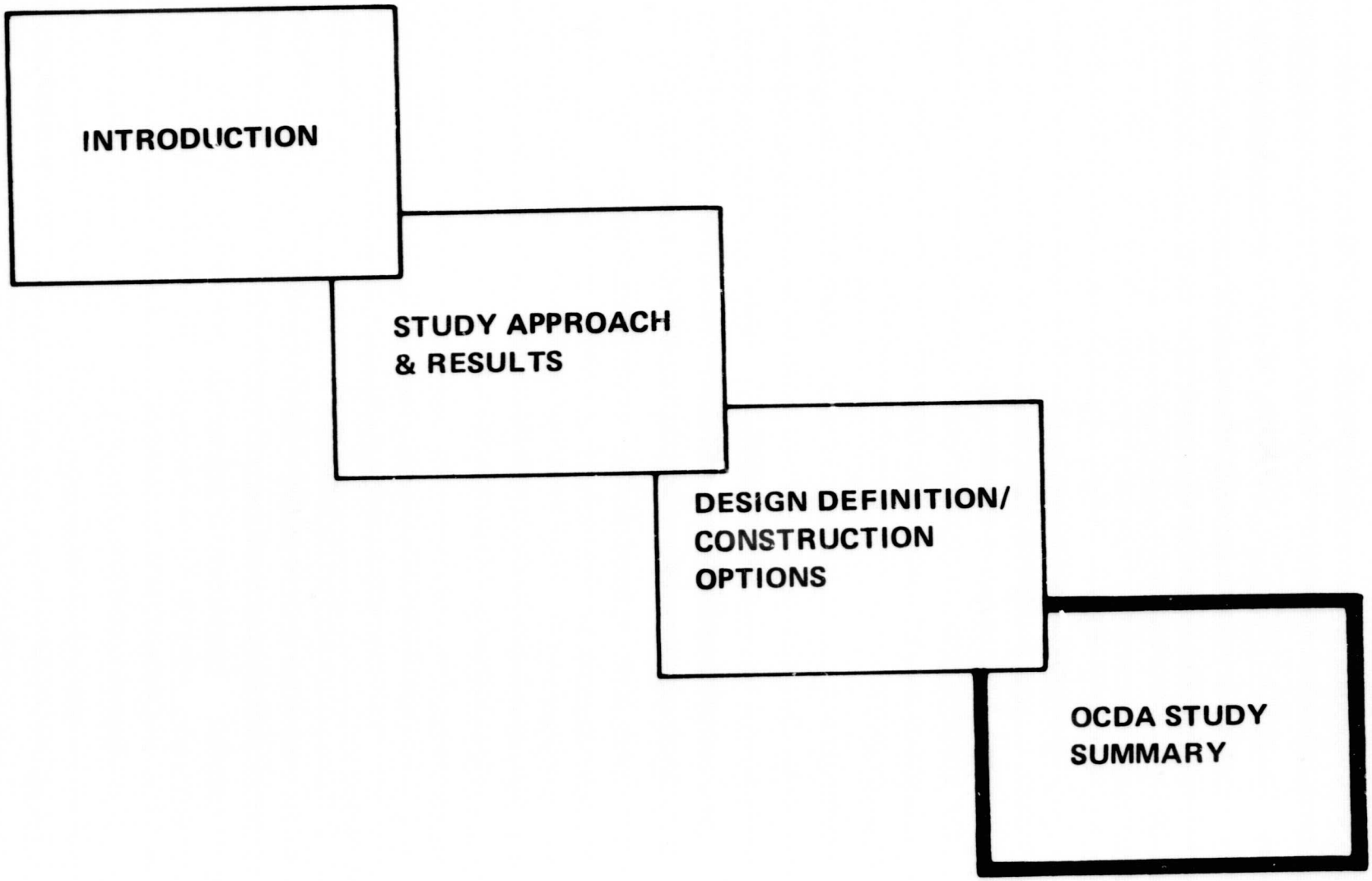
AGENDA



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OCDA STUDY SUMMARY

- ANALYZED REPRESENTATIVE MISSIONS (CHOSE 5)
  - SPS PHOTOVOLTAIC ARRAY
  - SPS SOLAR ARRAY
  - MPTS
  - LARGE RADIOMETER
  - NIGHT ILLUMINATOR
- IDENTIFIED 72 DEMONSTRATION OBJECTIVES
- SELECTED GENERAL PURPOSE CONSTRUCTION BASE CONFIGURATION
- MET PRINCIPAL MISSION OBJECTIVES WITH SELECTED CONFIG
- IDENTIFIED POTENTIAL FOLLOW-ON MISSIONS THAT ADDRESS REMAINING OBJECTIVES
- IDENTIFIED PROGRAMMATIC REQUIREMENTS FOR INITIAL DEPLOYMENT

CONCLUSION

- OCDA IS A VIABLE, MODERATE COST APPROACH TO RESOLVING KEY CONSTRUCTION TECHNOLOGY ISSUES, PAVING WAY FOR FUTURE MISSIONS

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RECOMMENDATIONS

- NASA SHOULD SERIOUSLY CONSIDER OCDA IN PLANNING FOR ADVANCING LARGE SPACE STRUCTURES TECHNOLOGY
- PLAN FOR 1984 IOC TO BENEFIT FROM OCDA TECHNOLOGY ADVANCEMENTS TO PERMIT KEY DECISIONS IN 1987 TIME FRAME ON ULTRA-LARGE STRUCTURES INITIATIVES LIKE THE SPS
- INITIATE PRECURSOR STUDIES (PHASES A & B) IN TIME FOR A 1979 NEW PROGRAM START DECISION, IF 1984 IOC IS TO BE MET

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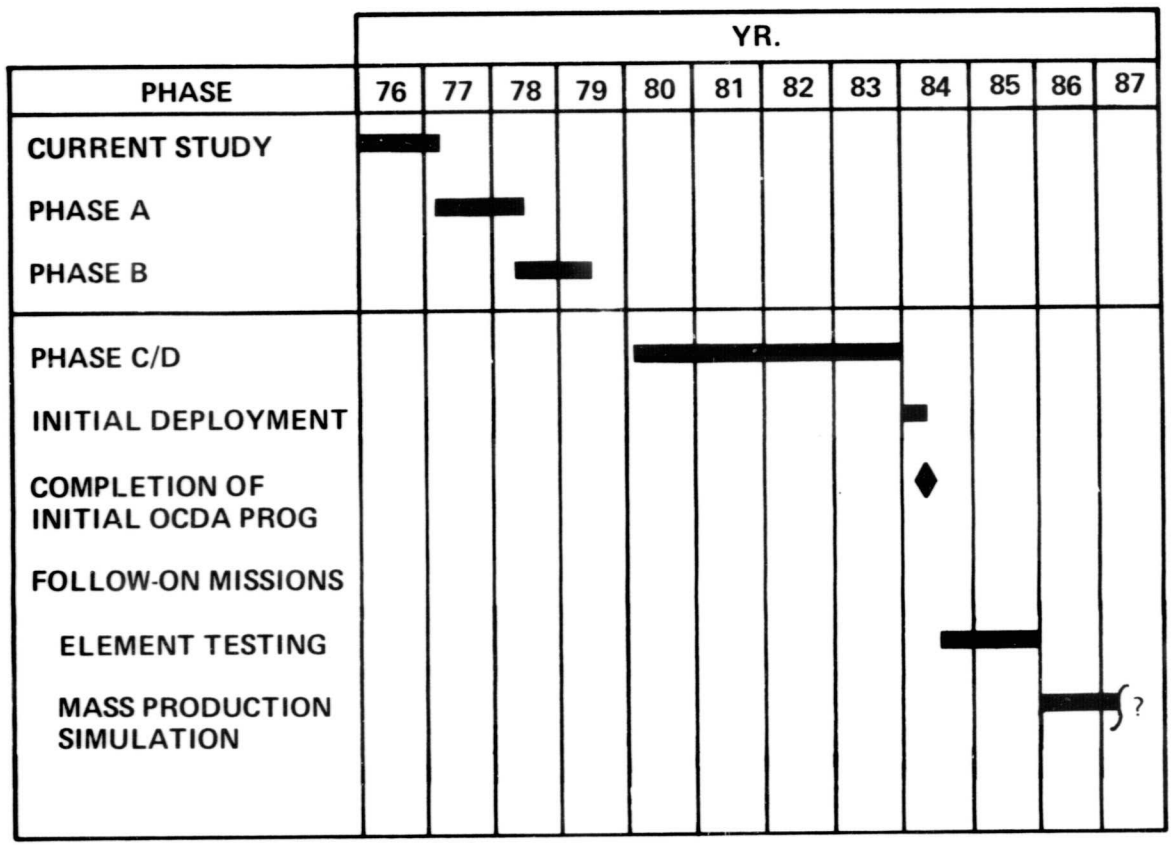
ORBITAL CONSTRUCTION DEMONSTRATION ARTICLE PLANNING SCHEDULE FOR SELECTED APPROACH



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